Watershed Monitoring and Assessment Design Workbook

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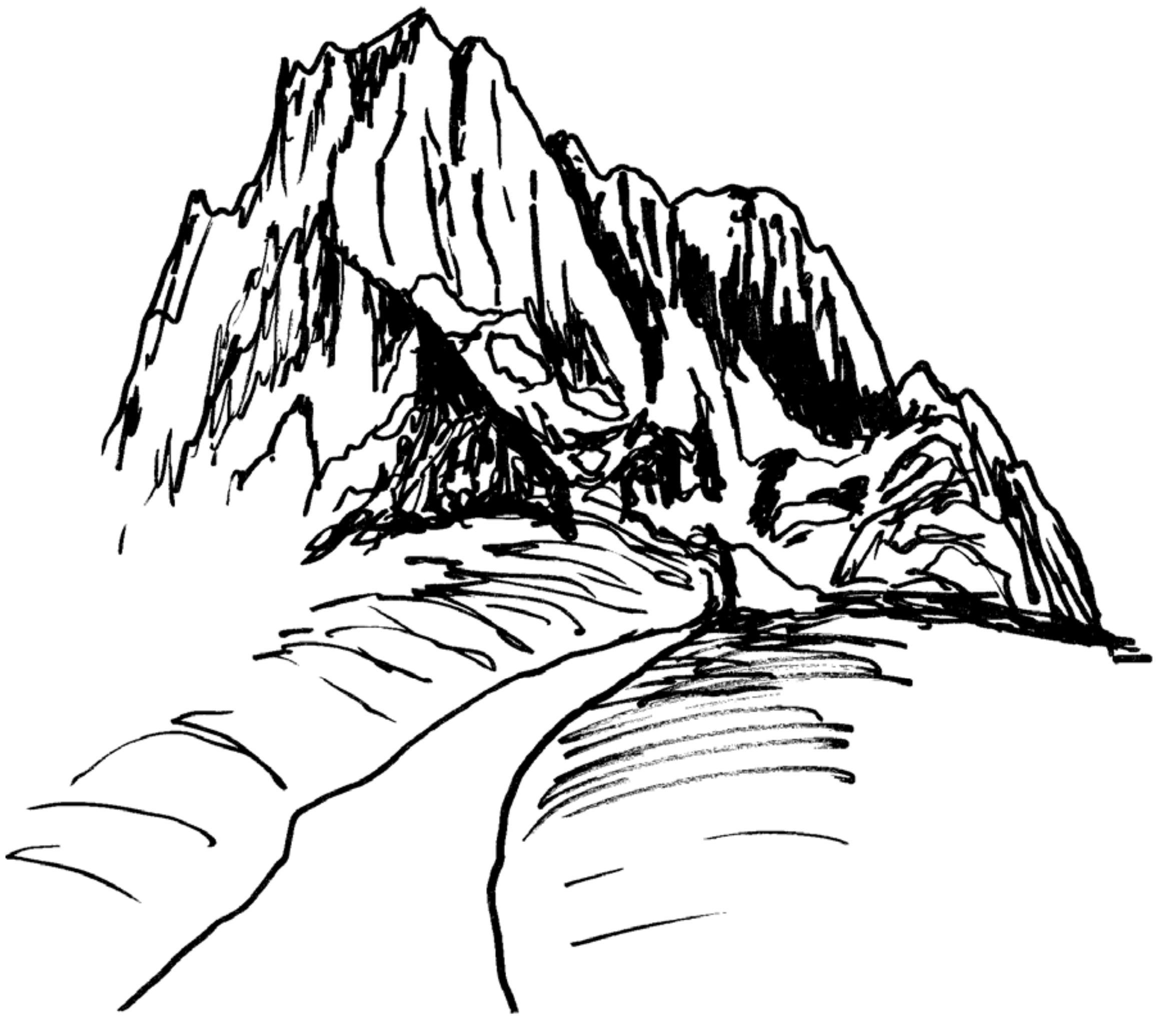

By Barb Horn and Geoff Dates

Funded by United States Environmental Protection Agency, Region VIII

Rocky Mountain Watershed Network Presents:

WATERSHED MONITORING AND ASSESSMENT DESIGN WORKBOOK

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PHASE 2: Technical Design: (Generate Data)

Step 7 – What Will You Monitor?
Step 8 – When Will You Monitor?
Step 9 – Where Will You Monitor?
Step 10 – (W)how Will You Monitor to Meet Data Quality Objectives?
Step 11 – Management of Raw Data (Data Management Plan Part 1)

Introduction and Summary of Phase 2

This phase focuses on what watershed characteristics you will be monitoring; how, where, and when you will be collecting and analyzing samples; and what quality your data must be to be useful. These technical decisions are driven by the information found and decisions made in Phase 1, Steps 1-6. Phase 1 provides in depth why you are collecting information for whom in the first place. You need to know all this information produced in Phase 1 because you want to be sure that the nuts and bolts of data collection, Phase 2, will meet the needs defined in Phase 1.

Phase 1 had you determine desired outcomes (based on a watershed vision), who is the keeper of this M & A Plan, combinations of monitoring reasons and a data use (user). These combinations were translated into one of the following Assessment Types, or one of your own:

A. **Condition and Trend Assessment:** Condition and Trend Assessment for wade able waters seeks to balance limited time and resources with the goal of sampling as many different aspects of the stream ecosystem as possible in as many different locations throughout the watershed as possible. The focus may be limited to relatively small areas or even particular reaches. It includes a wide range of monitoring activities that assess as many watershed ecosystem indicators as is practical for volunteer monitors, using relatively simple methods:

B. **Impact Assessment (both point and non-point source):** An Impact Assessment is the collection of selected information to establish the nature and extent of the impact of point and non-point source pollution sources (wastewater treatment plants and other permitted discharges, and various land uses) on the stream's ecological health and aquatic life uses. It includes a wide range of monitoring activities that assess as many of the physical, chemical, and biological indicators of stream health likely to be affected by the these sources as is practical for volunteer monitors, using methods appropriate to the data uses and users.

C. **Use Support Assessment:** A Use Support Assessment involves documenting whether the waters support their "designated uses" (e.g. aquatic life, water contact recreation, etc.). The results are compared with the criteria in the water quality standards applicable to each use (from Water Quality Standards). These criteria specify minimum or maximum levels or ranges necessary to support the uses.

D. **Effectiveness Assessment:** The focus of this assessment is to assess the effectiveness of various types of watershed restoration and protection actions. This is tailored to the uses and values being restored or protected. Usually, it will focus on determining whether the condition of the water supports the uses and values to be restored or protected. It may also include activities that provide an early warning of problems before the use is directly affected.

Phase 1 Step 4, had you refine monitoring reason and develop a series of monitoring questions for each Assessment Type. Phase 1 Step 5 had you refine data use into targeted decisions makers and further identify what decisions they would make and attempt to define what specific information they needed to make those decisions. The final Step in Phase 1 had you summarize this information for planning and communication through an Information Blue Print – Data Pathway Fact Sheet for every monitoring question per Assessment Type. This is part of the equation of information you need to develop an adequate sample collection design. The other part focuses on the science, such as accounting for variability with each Assessment Type.

The Effects of Variability on Your Assessment

Variability is a measure of how much something changes over time and space. For example, the difference over a year between your highest and lowest results at a single site for a given indicator is a type of variability over time. The difference between the results for a given set of sites on the same date is a type of variability over space.

Watershed assessment is all about measuring change. But it's critical to understand why changes occur:

1. **Some changes occur as part of natural cycles or processes:** A watershed is not static. It changes from minute to minute, day to day, and over seasons and years. For example, dissolved oxygen varies in response to the photosynthetic activity of green plants, which produces oxygen. This varies with the daily and seasonal cycles of the sun. Biological communities will change in response to natural upstream to downstream changes in habitat.
2. **Some changes are due to human activities:** Because modern society has greatly impacted watershed processes, human activities add another source of variability on top of those resulting from natural processes. For example, nutrients from runoff or sewage can generate higher than normal aquatic plant production.
3. **Some changes are due to errors in sampling or analysis:** In the process of assessing the watershed, you will introduce sources of variability in the ways that you collect and analyze samples. For example, measuring dissolved oxygen at two sites on the same day, but changing the calibration of the probe between the sites.

You are going to collect data that might be explained by any of these three. Naturally-occurring changes and those caused by human activities give you a true picture—they reflect what's really happening in the watershed. Assuming you can distinguish between the two, you can use this information to make protection and restoration decisions. Changes due to errors in sampling or analysis give you false signals. You might see a trend that isn't there, conclude that conditions are worse (or better) than they really are, etc. So, it's very important to select indicators that can be measured using methods that minimize this type of change (see the "How" chapter).

Assuming you minimize measurement errors, you're left with the challenge of distinguishing between the natural and human-caused changes you measure. If you intend to make management decisions based on your assessment, this is the main challenge in how you design your whole assessment, from selecting indicators through deciding where, when, and how you will carry it out.

Variability and Scale

Variability also depends on the scale, the relative size or extent of the area you are assessing:

- **Watershed:** An area of land that drains water, sediment and dissolved materials to a common outlet.
- **Stream Corridor:** The stream channel and plant communities on either side of the stream.
- **Stream:** The stream itself and its channel.
- **Stream Reach:** A relatively homogenous segment of the stream with relatively homogenous physical, chemical and biological characteristics. (FISRWG, 1998)

These different scales are not all well defined. For example, watersheds range in size from a few square miles (your local creek) to tens of thousands of square miles (the Yukon). To make matters even more confusing, other scales like "landscape" and "eco-regional," are often used. Like watersheds, these can be large or small. They are usually defined as an area with similar climate, natural biological communities, geology and other characteristics. These may cut across watershed boundaries. You may have several in your watershed. Knowing this may help you define your expectations of the changes that take place within your watershed as you move downstream.

Then there are areas defined by political boundaries, such as states, reservations, EPA regions, etc. These are not as useful in understanding your watershed as natural boundaries. But, they may be critical in defining the scale at which decisions about your watershed are made.

Typically, as the size of the assessment area increases, there will be a greater amount of variability to account for in the analysis of your results. For example, at the stream-reach scale, the factors that might affect the amount of sunlight to which the water is exposed and the consequent temperature of the water (e.g., elevation, stream width, canopy cover, aspect), don't vary as much as they do at the watershed scale. So if you are comparing sites from different parts of the watershed, you might have to group them by similar characteristics before you draw any conclusions about a change you measured.

Choosing the Scope of the Assessment

Choose the scope of assessment that will best address each of the questions you generated. Here are two basic assessment scopes (U.S. EPA, 1997):

1. **Comprehensive** - This is an approach that collects information, at the watershed scale, to get an idea of the general condition of watershed health over space and/or time. This assessment is concerned with the integrated "bottom line" effect of all the processes in the watershed. Thus you would not be specifically looking to determine or measure the cause of any problem. The comprehensive assessment is designed to be representative of all the different types of waters and lands within the watershed ("un-biased"). The comprehensive approach is most relevant to the following assessments:

- Condition and Trend Assessment and Use Support Assessment

2. **Targeted** - This describes an approach that collects information at the stream reach scale and/or the watershed scale. Unlike the comprehensive assessment (which strives for an un-biased sample of watershed conditions) the targeted approach focuses intentionally on one or more problem sources known (or suspected) to be causing problems. The information is used to assess the effect on the resource or people and the cause of the impact (pollution source or alteration). At the stream reach scale, you might target a pipe that is discharging pollutants into the river by assessing the water quality and/or aquatic life above and below it. You would select indicators that directly measure pollution levels, as well as indicators that respond to those pollutants. At the watershed scale, you might assess the effects of sediment loading (e.g., from erosion and deposition) on the watershed by measuring one of the major causes (e.g., % impervious surfaces) and the watershed's response (e.g., sediment loading, aquatic life or channel stability). You could also investigate whether or not there may be a connection between environmental contamination and human health problems. Direct assessment of the impact allows you to compare measurements and have what some would consider a better defense for a cause-and-effect relationship.

   The targeted approach is most relevant to the following assessments:

   - Impact Assessment or Effectiveness Assessment

Which Scale?

Finally, consider the advantages and disadvantages of different scales:

Large Scale

- Geographic extent can be large, so cumulative impacts are also assessed.
- Magnitude of the change in water quality at a representative site can be low due to dilution, but the duration of change will be longer due to a longer residual time.
- Changes detected are less likely to be influenced by ambient flows.

Loadings (concentration times flow) are more important than concentrations alone.

Small Scale

- Smallest geographic area to cover.
- Magnitude of change in water quality will be greater but duration will be shorter.
- Ambient flow conditions will exert a significant influence.
- Unless acute impacts are apparent, timelier monitoring will be required.
- In-water concentrations may be more important than loadings

Data Quality Objectives

This is a non-intuitive word that simply means "are mechanisms and tools that quantify and make sure the data you generate is of sufficient quality for the decisions it will be used for". This of course, requires identifying those decisions and the necessary quality. This is what you did in part in Phase 1. Phase 2 defines these as your starting point. These quality objectives are essential for measuring success or failure of the data collection and lab analyses efforts.

Raw Data Management

The last step in Phase 2 takes you through a planning and decision process to design a data management system to validate, transfer and store raw data and meta-data (information about the results). This includes inventory what data and meta-data you are producing, where, how and when, then planning and making decisions that result in valid data ready to go forward for analyses, interpretation, reporting and decision making. Included in this step are "system" decisions necessary to accomplish your goals.

The Steps in Phase 2 include:

Step 7: **What will you monitor?**
What indicators will you measure?

Step 8: **When will you monitor?**
What frequency, time of day, time of year?

Step 9: **Where will you monitor?**
Where will you collect and analyze samples?

Step 10: **(W)how will you monitor to meet data quality objectives?**
What sampling and analysis methods will you use, what quality of data is needed?

Step 11: **Management of Raw Data (Data Management Plan Part 1)**

How will you handle the raw data?

How to Use this Workbook

The overview section provides more introduction and basic background and information. It is highly recommended you read this before you start any Phase or Step. Each Phase and Steps are designed to develop and produce a Watershed Monitoring and Assessment Plan. Each Phase focuses on one critical aspect of an M & A Plan.

The format of each step is designed for you to understand 1) what you can accomplish, 2) why the products of this step are important, 3) what products you will produce, 4) basic steps (activities and worksheets) to produce the products, 5) worksheets and instructions, 6) background and content if you need more understanding to complete basic tasks, 7) case studies, 8) references and 9) resources. Four basic tasks are the same for each step. In the first two basic tasks we ask you to determine who should be involved in planning this step and to identify and evaluate what decisions have already been made regarding the specific step.

The last two basic steps involve putting the products of that step into a master Monitoring and Assessment Plan and to identify any needs you still have regarding that step in order to fully implement your M & A plan and place those in an Action Plan. Thus, both the Monitoring and Assessment Plan and Action Plan are accumulative, adding to an existing document and list after each step. At the end, you have a documented M & A plan and one of the last tasks has you prioritize your Action Plan (from all steps) on a timeline.

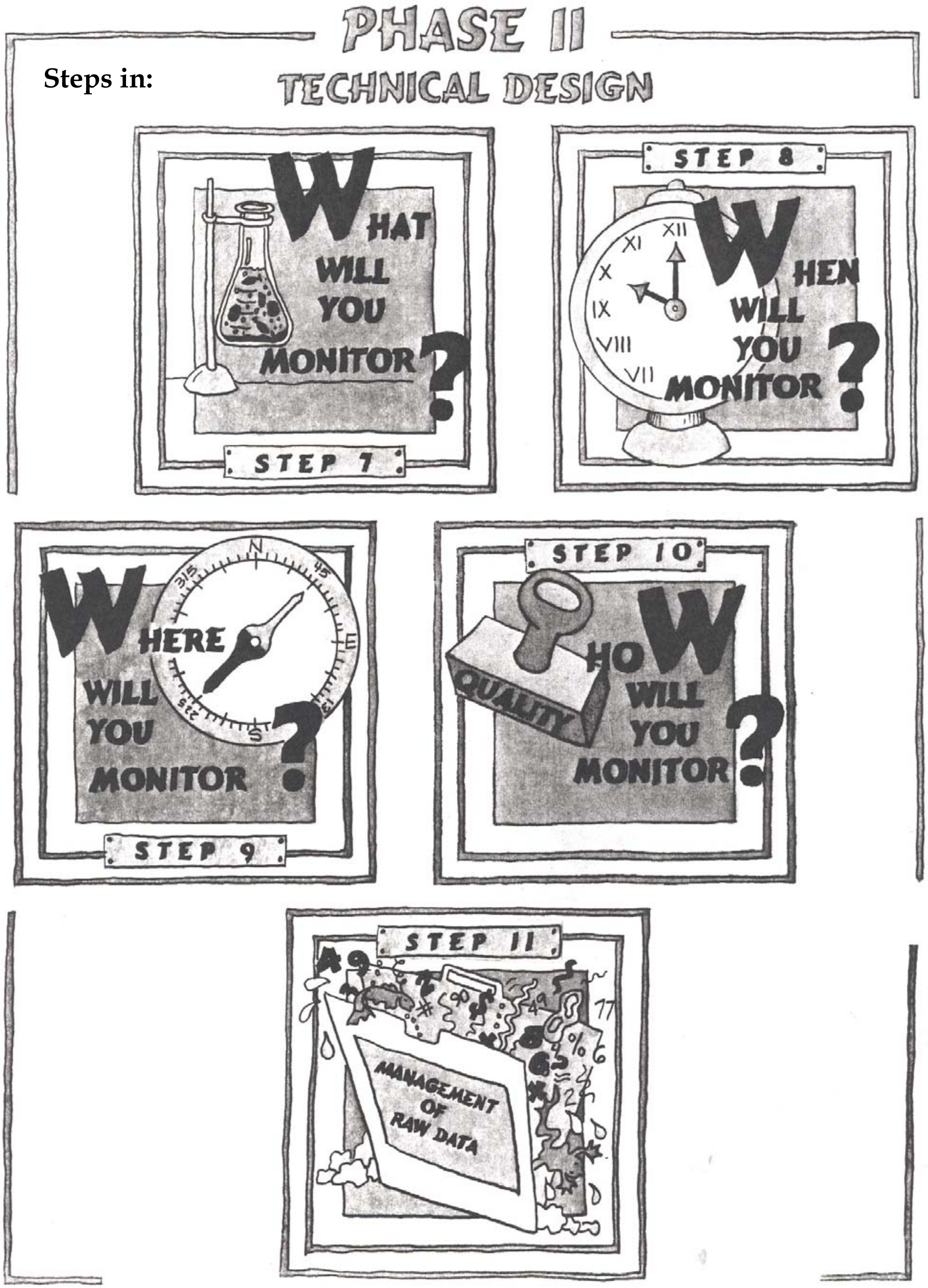
The worksheets are designed to be modified to meet your needs and completed electronically. However, they can be completed by hand as well. This is why they are simply formatted in word. The workbook comes with a compact disc for this purpose.

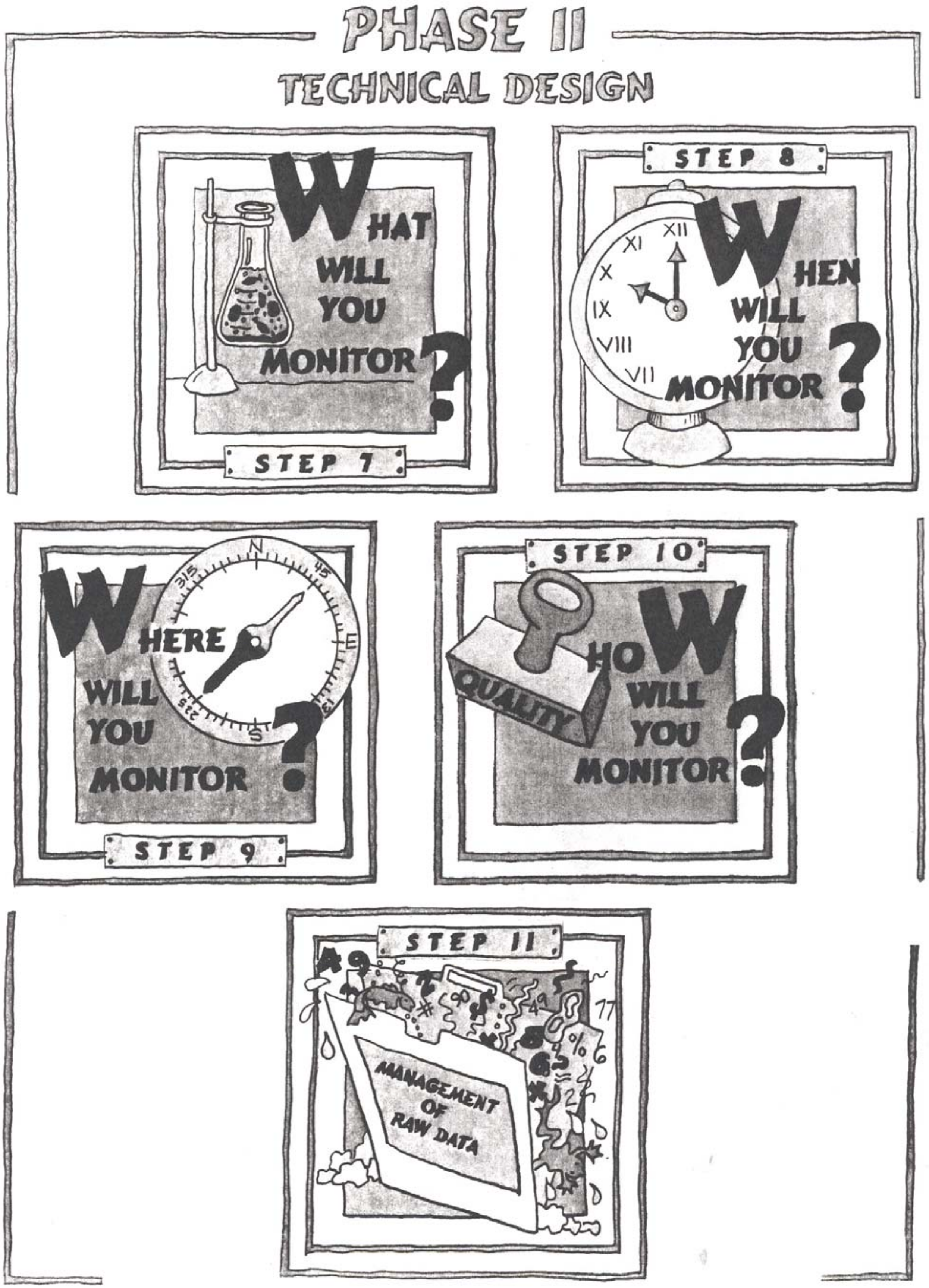
Remember that planning is dynamic, never complete, an iterative and not linear process. The amount of time and rigor you spend on each step is based upon your specific needs. If you skip a step, know why you skipped it. If you don't need to document or communicate or integrate components then don't, but know why.   We are suggesting that every monitoring and assessment activity should address or consider all Phases and Steps at the appropriate level.

Start where you are with what is known and expand your horizons. If the step seems too much for your needs, complete what you need and leave the rest. If it seems overwhelming, start with something and do it well. There is no right or wrong, no time limit, just start somewhere. Planning, implementing monitoring and assessment activities is not a black and white science. Embrace that you often will be "breaking trail", there is not clean answers for everything even though there are experts out there, but use what you can that they provide.

In the end if you can justify and articulate your monitor and assessment activities to someone, and can evaluate your results against your goals, then you have succeeded.

Watershed Monitoring and Assessment Design Workbook Phase and Step Illustration


PHASE II
Steps in:
TECHNICAL DESIGN
WHAT WILL YOU MONITOR?
STEP 7
STEP 8
WHEN WILL YOU MONITOR?
WHERE WILL YOU MONITOR?
STEP 9
STEP 10
HOW WILL YOU MONITOR?
QUALITY
STEP 11
MANAGEMENT OF RAW DATA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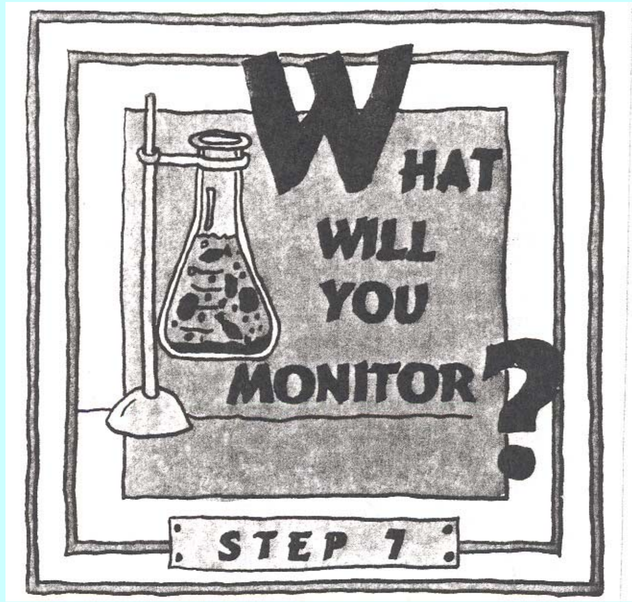
STEP 9
STEP 10
QUALITY
HOW WILL YOU MONITOR?
STEP 11
MANAGEMENT OF RAW DATA

Step 7: What Will You Monitor?



" Somebody has to do something, and it is just incredibly pathetic that it has to be us."

Jerry Garcia

About This Step – *This step is designed to accomplish 3 things:*

1. Understand the different types of parameters and indicators and how they relate to the sources of stress in your watershed
2. Consider the effects of scale and variability on your selection of parameters/indicators
3. Help you select the parameters and indicators you will monitor.

The focus of this step is to help you select the indicators you will monitor that will meet your purposes, the needs of your data user, and will be appropriate to your capabilities.

Because every characteristic of a watershed is related to many others, ideally, you would want to measure them all. Since that's not practical, monitoring and assessment programs focus on the ones that yield the most information for the least effort. They are sometimes called "parameters" and sometimes called "indicators." In much of the literature, these two terms are used interchangeably. In some, the term "indicator" is used as a calculated value that combines the results of measuring several characteristics into a single value.

The Intergovernmental Task Force on Monitoring Water Quality (ITFM) defines "environmental indicator" as follows: "A measurable feature which singly or in combination provides managerially and scientifically useful evidence of environmental and ecosystem quality or reliable evidence of trends in quality." We're going to try and be consistent:

Parameter: We'll try to use this term to mean a single characteristic, like dissolved oxygen, turbidity, depth, etc. Further, we'll tend to use this term mostly in connection with physical and chemical characteristics of the water column.

Indicator: We'll try to use this term to refer to characteristics that are calculated (e.g., benthic macroinvertebrates, etc.) or used in combination such as % saturation of dissolved oxygen (calculated from the DO concentration and water temperature) and biological communities (e.g. benthic macroinvertebrates, fish).

Notice that we said we'll *try* . . .

Why Do This Step

You can't measure everything relevant to your monitoring question and watershed. Watersheds are complex systems of physical, chemical and biological characteristics. So, you need to focus on measuring those that will give you the most information for the least amount of time, effort, and money. You also should know why you need each indicator you select, what purpose each indicator serves in achieving desired outcomes.

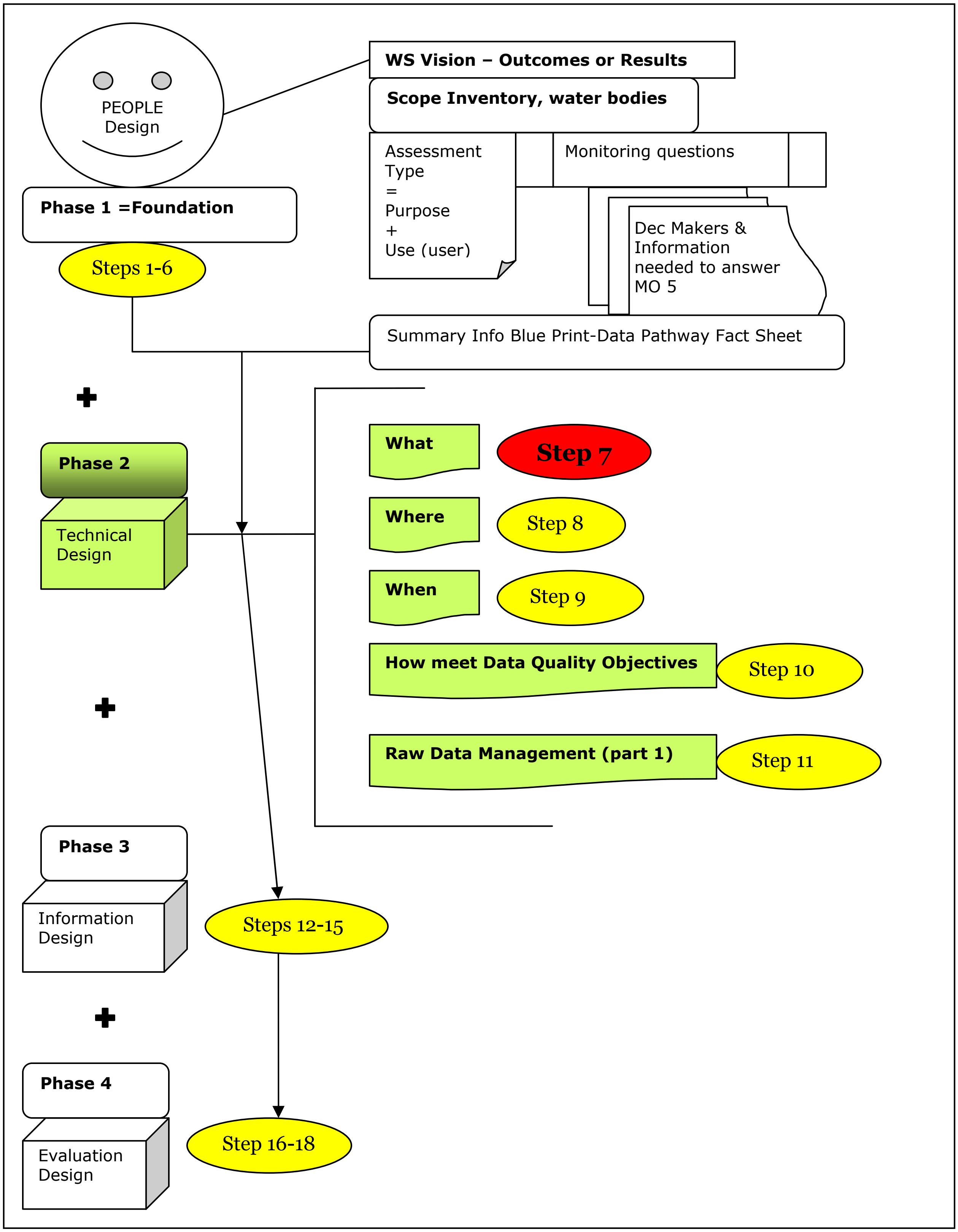
Where are we in the Big Picture Illustration?

Phase 1	Step 1: Share Watershed Vision and Desired Outcomes (Results) Step 2: Scope Inventory (Physical, People and Information) Step 3: Identify Monitoring Reason(s) and Data Use(s) (Assessment Type) Step 4: Develop Monitoring Questions (Refinement of Monitoring Reason) Step 5: Target Decision Makers and Info Needs (Refinement of Data Use) Step 6: Summarize with Information Blue Print-Data Pathway Fact Sheet)
Phase 2	**Step 7: What Will You Monitor?** Step 8: When Will You Monitor? Step 9: Where Will You Monitor? Step 10: How Will You Monitor to Meet Data Quality Objectives? Step 11: Management of Raw Data (Data Management Plan Part 1)
Phase 3	Step 12: Data Summary and Analysis Step 13: Interpretation, Conclusions and Recommendations Step 14: Communicating and Delivery Step 15: Management to Generate Info (Data Management Plan Part 2)
Phase 4	Step 16: Who Will Do What? Task Identification Step 17: Evaluation of Effectiveness (of Plan and Implementation) Step 18: Documentation and Communication (of M & A Plan)

Product (see Figure Phase 2 Product List):

√ A list of sources (stressors) and parameters that will be monitored to answer each monitoring question per Assessment Type (unique combination of one monitoring reason and one data use/user).

Phase 2 Product Illustration:



What Should Be Done Before This Step

The information listed in the Final Information Blue Print-Data Pathway Fact Sheet, Worksheet 6.3.a in Step 6. This information needs to be provided for every monitoring question per each Assessment Type. The summary sheet should be completed as much as possible but is a starting point. Worksheet 5.4.a and 5.4.a lists the information needed by targeted decision makers and associated data quality objectives. You may also have found valuable information from the Scoping Inventory, especially Worksheet 2.9.a, Worksheet 2.11.a, Worksheet 2.12.a and Worksheet 2.13.a.

- Worksheet 6.3.a is the summary Information Blue Print – Data Pathway Fact Sheet for each monitoring question per Assessment Type, selection of Assessment Type was Worksheet 3.4.a.
- Worksheet 5.4.a and 5.4.b, information needed by targeted decision makers and associated data quality objectives
- Worksheet 2.9.a, Physical Attributes of target water bodies
- Worksheet 2.11.a, Impact Features of target water bodies.
- Worksheet 2.12.a Water body stressor Identification.
- Worksheet 2.13.a Water body Status and/or condition

The assessment type narrows down the parameters you need to consider. Further, tables later in this chapter will help you narrow the field even further.

Steps 1 through 6, Phase 1, do not need to be completed per say, but the information that is a result of those steps are necessary to identify and define to design the monitoring components of what, when, where and how you will gather data. This information is also necessary to plan how the data will generate information, be managed, analyzed, interpreted, delivered to decision makers and evaluated. Information generated in Steps 1-6, Phase 2 are the foundation of every monitoring program.

Thus, ideally you need to have identified a watershed vision and desired outcomes with associated assumptions and external factors. Defined combination of *monitoring reason*s and uses, we call Assessment types. For each assessment type a list of monitoring questions the data is to answer and how that question will be answered. For each monitoring question, a list of targeted decision makers, their decision, how they make that decision and what information they need to make the decision. Once you have this, you can summarize the results in any format, we suggests the information blueprint – data pathway fact sheet from Step 6, Worksheet 6.3.a.

Basic Tasks

Basic Tasks are numbered to correlate with the overall 1-18 Steps provided in these guidance modules followed by the basic task sequence step to complete. For example Step 4, basic task 2 would be numbered as Basic Task Step 4.2, Step 3.3 correlates to Step 3, Basic Task 3.

7.1 Identify who will make the decisions about this step and who should be involved in the planning process (they may be different).

7.2 Self Assessment: If you've been monitoring before you've undertaken this process, have the parameters you've measured worked well?

7.3 Types and sources of stress or impairment in your watershed that you want

7.4 Parameters/indicators and Scale. This will define a large part of the size of your effort.

7.5 Reality Check of each monitoring question, data pathway, cost estimate and effort against organization mission and resources, adjust plans accordingly.

- ✓ Does the assessment type you chose meet your information needs?
- ✓ Meet the needs of your targeted decision maker?
- ✓ Do you have the capacity to carry it out?

7.6 Update *Inventory Master List* and *Plan.*

7.7 Update *Information Blueprint – Data Pathway Fact Sheet* for each monitoring question.

7.8 Place Products in your *Watershed Monitoring and Assessment Plan*.

7.9 Place your identified gaps and needs regarding this step in the *Action Plan* (what you need to plan to complete this step and or overall monitoring and assessment plan).

Worksheets

Work sheets are listed below. Not all Basic Tasks have an associated work sheet. To simplify completion of products for each step, the worksheets or broken into small subsets of tasks. This requires moving the results of one task into the next task and will seem redundant, especially if completing worksheets by hand. Worksheets are provided in word here for ease of reproducibility. These are a starting point; we encourage you to customize these and reproduced them in an electronic format, in Excel for example, where it is easy to move information from one area to another by cutting and pasting.

Work Sheets are numbered to correlate with Basic Steps and the overall Steps in these guidance modules. Each consecutive work sheet is lettered a, b, c and so forth, preceded by the Basic Task sequence step, preceded by the Step number. For example, Worksheet Step 4.2.a and Step 4.2.b, correlates to Step 4, Basic Task 2, Worksheet a and Worksheet b. In theory worksheet a needs to be completed before worksheet b.

Worksheet 7.2.a **Self Assessment Step 7 Worksheet and Products to be completed Prior to this Step, Part 1 and Part 2.** If you've been monitoring prior to using this planning process, you've got some experience with some of the parameters. In this worksheet, you will evaluate the use and effectiveness of your current parameters.

Worksheet 7.3.a **Sources of stress or impairment in your watershed.** In this worksheet, the main idea is to recap the stressors that affect the quality of your watershed. If you've done the inventory in step 1, you may already have a good list. This worksheet will help refine it.

Worksheet 7.4.a **Parameters/indicators you will measure and the scale at which you will measure them.** Refer to the assessment type(s) you selected in Step 3 and recorded in Worksheet 3.4.a. Refer to the Information needs developed for each selected decision maker in Worksheet 5.3.a and 5.4.a. If you summarized all information for each monitoring question, you can use what you found from the Information Blue Print-Data Pathway Fact Sheet, Worksheet 6.3.a.

Worksheet 7.8.a **Place Products in your** *Watershed Monitoring and Assessment Plan.*

Worksheet 7.9.a **Place your identified gaps and needs regarding this step in the** *Action Plan* **(what you need to plan to complete this step and or overall monitoring and assessment plan).**

How to do Worksheets

For Sheet 7.2.a Self Assessment Step 7 Worksheet and Products to be completed Prior to this Step.

Part 1. Complete the self assessment section of the worksheet to evaluate what you have or what decisions have already been made. This will help you focus on what you need from this step and incorporate valuable existing information or products into this plan.

Part 2. Next, to prepare to complete this step the following, you need to have the following items addressed:

- ✓Desired set of outcomes or results that the monitoring and assessment activities will be designed to help achieve
- ✓Identified monitoring and assessment activities, specific combinations of a monitoring reason plus an associated data use; we call this an Assessment Type. You may have multiple Assessment Types.
- ✓For each Assessment Type, the list of specific monitoring questions the monitoring and assessment will be designed to answer.
- ✓For each monitoring question, the targeted decision makers, the type of decisions they will make and the information they need to make them (as specific as possible).
- ✓A minimal scoping inventory that identifies the watershed boundary and water bodies you are focusing on (rivers, lakes or wetlands), physical attributes of water bodies (including status, uses, etc.), relevant cultural or historical aspects, existing data sets or monitoring efforts and others in the watershed who either you want to influence or could help you implement.
- ✓Technical sample plan including what monitor (indicators, benchmarks, criteria, etc.), where and when monitor, how will meet data quality objectives (methods, how good does the data need to be for decision makers, quality assurance and control measures), and how will manage and verify raw data/information- AT THIS POINT WHAT YOU KNOW, if you don't know it, Phase 2 and 3 help you determine these items.

This is the ideal list, if you do not have any of these, they become a gap or need that should be addressed before any data is collected or analyzed, even if the answers aren't perfect or you don't have a large degree of confidence surrounding them, they should be attempted as the starting point. This is what you are evaluating in this step-your monitoring and assessment plan.

Worksheet 7.2.a Self Assessment Step 7 Worksheet and Products to be completed Prior to this Step. Part 1.

Part 1 Self Assessment of Known Evaluation Products and Processes

1. **Determine if you "have" or "don't have" the item, mark the appropriate box. If you don't have it and determine you don't need it, explain why in the comments document. You may not need to know but perhaps your target decision makers, board or membership might want to know.**

2. **If you have the item "documented", mark that box. If so, list in the comments where, hard copy, chapter in a document, electronic file name and location, etc. The assumption is you value the ultimate goal to document and communicate your M & A plan, activities and results.**

3. **If you have the item, assess the use of it, use the scale below or provide your own answer and comments.**

   Rating Scale for USE:
   - 0=doesn't exist so use is nil
   - 1=don't know why would need or understand item
   - 2=exists, don't know where it is, if it is used, etc. so use is essentially nil
   - 3=exists and use some of time
   - 4=exists and use all the time
   - 5=wish it existed, would use it lots

4. **If you have the item, assess the effectiveness of it, just because something exists or is used does not mean it is effective in its use, use the effectiveness scale below or provide your own answer and comments.**

   Rating Scale for EFFECTIVENESS, assumes material exists:
   - 0=not effective or functional at all
   - 1=incomplete (all elements are not there) and some existing parts need revising
   - 2=incomplete but what is there is okay
   - 3=complete (all elements are there), some parts okay but need revising
   - 4=complete and effective

Item	Have	Don't Have	DOC	Assessment of Use (Scale 0-5)	Assessment of value / effectiveness (Scale 0-4)	Comments/Notes
23. Written Technical/sample or monitoring Plans, includes overall monitoring goals- what, when, where, how						
24. Identification of what, indicators, parameters, benchmarks, etc.?						
Other?						

*DOC=Documentation, *M & A= Monitoring and Assessment

5. **To make this assessment useful, determine what your gaps and needs are regarding this step in order to focus your effort in completing this step.**

Worksheet 7.2.a Self Assessment Step 7 Worksheet and Products to be completed Prior to this Step. Part 2.

Part 2 Products to be completed before this step, in order to complete this step, what know from Step 5 and Step 6, Worksheet 6.3.a. If you don't know, you will after this Step.

Item	Response
Desired set of outcomes or results that the monitoring and assessment activities will be designed to help achieve:	
Assessment Types, specific combination of one monitoring reason and data use(r):	
For each Assessment Type, the list of specific monitoring questions:	
For each monitoring question, the targeted decision makers, the type of decisions they will make and the information they need to make them (as specific as possible):	
Watershed(s) and Water bodies of focus:	
Physical attributes of Water bodies (status, use, etc.)	
Existing Data or monitoring efforts:	
Indicators, benchmarks and criteria list:	
List of monitoring locations/rationale:	
List of monitoring frequencies:	
Methods list, list of data quality objectives (methods, how good does the data need to be for decision makers), quality assurance and control measures)	
What you know now about decision makers data-to-information needs, analyses, interpretation and reporting	

For Sheet 7.3.a **Sources of stress or impairment in your watershed. In this worksheet, the main idea is to recap the stressors that affect the quality of your watershed. If you've done the inventory in step 1, you may already have a good list. This worksheet will help refine it.**

7.3.a Example Stressors: Causes and Sources

Watershed Stressors	Sources (Stressors)							
	Sew	Tox	Ero	Nut	Ani	Urb	Veg	AMD
Causes of Stress								

Key to sources of stress:
Sew = sewage Tox = toxics Ani = animal manure Veg = streamside vegetation removal
Ero = erosion Nut = nutrients Urb = urban runoff AMD = abandoned mine drainage

In the left-hand column, list the stressors (the causes of stress). For example, *sediment* might be one of your list. In the other columns to the right, put a check or fill in the boxes under each of the known (or suspected) sources of sediment that you know are present.

Worksheet 7.4.a **Parameters/indicators you will measure and the scale at which you will measure them. Refer to the assessment type(s) you selected in Step 3 and recorded in Worksheet 3.4.a, Worksheet 5.3.a and 5.4.a the information needs of the targeted decision makers, if you knew them.**

For each assessment type, list the stressors and their associated parameters/indicators, and the scale at which you will monitor in Table 7.4.a. Use the recommended list of parameters and indicators in the above assessment tables. Remember that the indicators listed for each assessment are a menu – you don't have to monitor all of them! Your human and financial resources and expertise may limit the indicators you can monitor. Find out how much time, money, equipment and expertise are required to monitor each indicator.

You'll need to consult with members of your technical committee, who are familiar with how these indicators are sampled and analyzed. You may want to revisit your selections after you have determined your data quality objectives and methods. Remember that selecting indicators is a logical process that considers your specific monitoring question and your capabilities. And, you have set up a technical committee to help you make these choices (right?!).

Worksheet 7.4.a Select and List Parameters

List the stressors you checked and the parameters and scale for each one.

Sources (stressors)	Parameters	Scale

Things to consider when selecting indicators:

Scientific Considerations:

- Does it help answer your question?
- Can you observe or measure and quantify it?
- Does it respond to changes over a reasonable time period?
- Does it respond to the impacts you're evaluating?
- Can you isolate the conditions that cause it to change?
- Does it integrate effects over time and space?
- Does it respond to changes in other indicators?
- Is it a true measure of an environmental condition?
- Is there a benchmark or reference condition against which to evaluate it?
- Does it provide early warning of changes?

Practical and Program Considerations:

- Do you have the human and financial resources to measure it?
- How difficult is it to monitor?
- Does it help you understand a major component of the ecosystem?
- Is it understandable/explainable to your target audience?

For Sheet 7.8.a **Place Products in your** ***Watershed Monitoring and Assessment Plan*****.**

- For each Assessment Type, combination of monitoring reason and data use, and associated list of monitoring questions, add all potential indicators that will answer your monitoring questions.

Worksheet 7.8.a **Add products of Step to** ***Watershed Monitoring and Assessment Plan.***

If you completed any Steps this Worksheet is cumulative, use that document. If you have not you complete that aspect that is highlighted for your plan documentation. **Italics mean a sub plan that might be attached or live somewhere else, location of document and contact is what would go in the plan.*

I. People Design, Phase 1

   A. Shared Watershed Vision and Desired Outcomes (Step 1)

      1. Logic Model of Desired Outcomes/Results and activities/target audiences to employ to achieve outcomes

   B. Keepers of the M & A Plan (Step 1)

   C. Watershed Boundary (Step 2)

   D. Water bodies of Interest (Step 2)

   E. Scope Inventory Master List* (Step 2)

      1. Physical Inventory * (Step 2)

      2. People Inventory* (Step 2)

      3. Information Inventory* (Step 2)

         a. Existing Monitoring Efforts (Step 2)

         b. Existing Data Sources (Step 2)

      4. Inventory Action Plan* (Step 2)

   F. Assessment Type(s) List – Monitoring Reason + Use (Step 3)

      1. Monitoring Question(s) (Step 4)

      2. Targeted Decision Maker(s) (Step 5)

         a. Information Needs (Step 5)

      3. Information Blue Print – Data Pathway Fact Sheet Per Monitoring Question* (Step 6)

II. Technical Design, Phase 2

   A. What (Indicators, Benchmarks, etc.) and why? (Step 7)

   B. When and why? (Step 8)

   C. Where and why? (Step 9)

D. W(how) will meet data quality objectives? (Step 10)

1. Data quality objectives (Step 5 and 10)
2. Quality Assurance and Control Measures (Quality Assurance and Control Plan)* (Step 10)

E. Data Management for Raw Data (Data Management Plan Part 1)* (Step 11)

III. Information Design, Phase 3

A. Data Summary and Analyses (Step 12)

1. Starting Point (Step 12)
2. Changes (Later)

B. Data Interpretation, Conclusions, Recommendations

1. Starting Point (Step 13)
2. Changes (Later)

C. Communication and Delivery

1. Starting Point (Step 14)
2. Changes (Later)

D. Management Plans to Generate Information (Data Management Plan Part 2)* (Step 15)

IV. Evaluation Design, Phase 4

A. Who Will Do What? (Step 16)

1. Task Identification Matrix (Step 16)
2. Communication Structure and Tools (Step 16)

B. Evaluation Plans (Step 17)

1. Evaluation Plans for M & A Components (Step 17)
2. Evaluation Plans for M & A Implementation (Step 17)
3. Evaluation of inter/intra M & A Activities (Step 17)

C. Documentation and Communication (Step 18)

1. M & A Plan (**this document**, updated Sub documents) (Step 18)
2. Communication and Peer Review Plan (Step 18)
3. Action Plan* (Step 17)

For Sheet 7.9a **Place your identified gaps and needs regarding this step in the *Action Plan* (what you need to plan to complete this step and or overall monitoring and assessment plan).**

Worksheet 7.9.a **Final** *Action Plan* **Part 1, Summary:**

If you have completed each Step, or for those you have, you have a cumulated list of gaps and needs related to that Step. Use that same worksheet/document. If you did not complete each Step, look at what each Step is supposed to accomplish and record what your gaps and needs are related to that topic. The goals are to get the gaps and needs in one place to evaluate and prioritize.

Phase 1 Step 1: (completed in Step 1)
Phase 1 Step 2: (completed in Step 2)
Phase 1 Step 3: (completed in Step 3)
Phase 1 Step 4: (completed in Step 4)
Phase 1 Step 5: (completed in Step 5)
Phase 1 Step 6: (completed in Step 6)
Phase 2 Step 7:
Phase 3 and 4 Steps: Will add Action and Needs as complete each Step and at the end prioritize

Background and Content

Watersheds are very complicated systems of inter-related physical, chemical and biological characteristics, often referred to as "indicators[1]." Which indicators you choose to monitor will depend upon your monitoring goals and objectives, as well as your available human and financial resources. There are literally hundreds of indicators that you could measure. Rather than list them all here, we'll organize them into two broad categories and give you a few examples from each: 1) watershed ecosystem indicators, and 2) public health indicators.

Ecosystem Indicators Recommended by the Inter-governmental Task Force on Monitoring

Biota

Community Level Data from At Least 2

- Fish Assemblages
- Benthic Macroinvertebrates
- Periphyton

Habitat

- Channel Morphology
- Flow
- Substrate Quality
- Riparian Vegetation

Chemical Water Quality

- pH
- Temperature
- Conductivity
- Dissolved Oxygen

Different Ways of Looking At Watershed Ecosystem Indicators

Biological Indicators: This includes living things like bacteria, fish, insects, plants and others living in the water column or on the bottom of a water body or in the riparian area.

Physical Water Column Indicators: This includes factors like temperature, turbidity, clarity and other physical characteristics of the water column.

Chemical Water Column Indicators: This includes factors like dissolved oxygen, pH, alkalinity, nutrients and other elements and compounds found in the water column.

Flow Regime: This includes all the factors that affect the amount of water in the system, such as land use, precipitation, runoff, groundwater and current velocity.

Habitat Structure: This includes the physical structure of the channel, shorelines and riparian area that supports life, such as riparian vegetation, bottom composition, bank stability, and gradient, in stream cover, current, channel form, siltation and width/depth.

Energy Source: This includes the various factors that provide energy to watershed organisms such as sunlight, organic matter inputs, nutrients, oxygen and carbon dioxide production.

The different indicators listed above each tell us something different about the stream or lake. One way to think about these differences is to think about those factors that stress the watershed, the exposure of the watershed to that stress, and how it responds. This stress, exposure and response way of thinking is similar to how people who study the occurrence of disease think about their work.

[1] The Intergovernmental Task Force on Monitoring Water Quality (ITFM) defines "environmental indicator" as follows: "A measurable feature which singly or in combination provides managerially and scientifically useful evidence of environmental and ecosystem quality or reliable evidence of trends in quality." ITFM, 1993 Report, Technical Appendixes, Appendix A.

- **Watershed Stress Indicators:** These are measures of activities which have the potential to affect the ecosystem, (e.g. pollution, land uses, water uses, climate, etc.).
- **Watershed Exposure Indicators:** These are measures of changes in indicators that suggest the magnitude and duration of exposure to a stressor (e.g. the concentration of suspended sediment over a period of time, the duration of low flow and/or high temperature events.).

Watershed Response Indicators: These are measures of the ecosystem's response to exposure to a stressor (e.g. changes in the river channel, changes in biological community composition or abundance).

This is a useful way to think about indicators because it helps you select appropriate indicators based on how you will use the information. For example, just because you measure higher-than-normal nutrient concentrations, doesn't mean you have discovered a problem (unless there is a violation of water quality standards). To assess that, you will need to measure a response indicator, to see if those higher-than-normal concentrations are actually causing problems for aquatic life.

Public Health Indicators

You can think of public health indicators in much the same way as watershed health: stress, exposure and response. In this case, stress would be the presence of disease-carrying organisms in the water (high levels of E. coli bacteria in water used for swimming or drinking). Exposure would be the extent to which people come in contact with disease-carrying organisms (e.g. the extent to which people are drinking or swimming in contaminated water). Response would be the extent to which people exposed to a contaminant actually get sick (e.g. number of illnesses in people who drink or swim in the water with high levels of bacteria). In this workbook, we have simplified the task of choosing indicators by packaging them into "assessments."

Scale and Variability

For every indicator you will have to consider the effects of scale on:

- Natural variability: For example, at the stream scale, high elevation headwater streams are typically colder and have more shading than streams at lower elevations. If you found a measurable difference in dissolved oxygen levels when comparing a high and low elevation stream, it could be primarily a result of this natural variability.
- Human-induced variability: For example, at the watershed scale, smaller watersheds may have fewer differences in land use activities than a large watershed-making it easier to pinpoint the source(s) of nutrients coming into a stream.

Sampling and analysis variability: For example, dissolved oxygen levels will naturally increase as the day progresses due to increasing photosynthesis as the sun gets higher in the sky. If you are sampling many sites throughout a large watershed, it will be difficult to measure dissolved oxygen levels at all the sites, within a small enough period of time, so that the level of sunlight doesn't affect your results. Thus, even if the sites are similar, measurable differences might be caused by time of day.

Picking Indicators for Your Assessment

Now it's time to select the indicators you will measure. The tables on the following pages are designed to help you do that. First, refer back to your inventory. List all the stressors - sources of pollution and other human alterations of the watershed. If you haven't done the inventory yet, we suggest that you consider starting with the following inventory:

Pollution and Alteration Sources Inventory		
Activities:	**Purpose:**	**Method:**
A. Point Pollution Sources (e.g. discharges) B. Land-based Non-point Pollution Sources (e.g. urbanization) C. Altered Flows (e.g. Dams, water withdrawals, diversions)	To determine the potential sources of pollution and alterations to the aquatic ecosystem and human uses.	Research Existing Information Uses, Values, and Threats Survey Windshield Surveys Stream-walks Pipe inventories

Once you've identified your stressors, you're ready to pick indicators (sometimes called parameters) to measure from the following tables. These are organized by the monitoring purpose you identified in Step 3:

A. **Condition and Trend Assessment:** The indicators you select for this purpose should be ones that you can reliably monitor on a long-term basis – think in 5-10 year terms – and that represent different aspects of the watershed ecosystem (see the different ways of looking at indicators.

B. **Impact Assessment (both point and non-point source):** The most important indicators are those that are most sensitive to the particular sources and causes. The time frame may be short – perhaps only one season - for some of the indicators you measure. So, response indicators are particularly important here. Remember that this may evolve into an effectiveness assessment, so be sure to pick indicators that you would continue monitoring throughout both assessments.

C. **Use Support Assessment**: This may be the easiest assessment for which to select indicators: focus on those for which there are criteria in the water quality standards.

D. **Effectiveness Assessment:** The indicators you select for this assessment depend entirely on the nature of the protection and restoration measures. Be sure to select the ones that will respond to new threats (if your action was protection) and reduction in impacts of existing sources (if your action was restoration.

Notice that there are two categories in each table: indicators that are causes of stress and indicators that respond to stress. *It's very important to pick indicators from each group.*

A. Condition and Trend Assessment: Stressors and Recommended Indicators

	Sources (Stressors)							
Parameters/Indicators	Sew	Tox	Ero	Nut	Ani	Urb	Veg	AMD
Causes of Stress								
Fecal colif./E. coli Bacteria	X				X	X		
Total Phosphorus	X		X	X	X	X	X	
Total Dissolved Phosphorus			X	X				

Parameters/Indicators	Sources (Stressors)							
	Sew	Tox	Ero	Nut	Ani	Urb	Veg	AMD
Nitrogen Series								
- Total Kjeldahl Nitrogen				X	X	X	X	
- Nitrates	X			X	X	X		
- Ammonia	X							
Turbidity	X		X		X	X	X	
Dissolved Oxygen			X	X	X	X	X	
Biochemical Oxygen Demand	X							
Temperature	X		X	X	X	X	X	
pH	X	X				X		X
Total Alkalinity	X	X				X		X
Acidity								X
Conductivity	X					X		X
Hardness		X						
Total Iron								X
Manganese								X
Sulfates								X
Aluminum								X
Total Dissolved Solids	X							
Total Suspended Solids	X		X					
Total Residual Chlorine	X							
Response Indicators								
Benthic Macroinvertebrate Assessment	X	X	X	X	X	X	X	X
Benthic Macroinvertebrate Habitat Assessment	X	X	X		X	X	X	X
Embeddedness			X			X	X	
Channel cross - sections			X			X	X	
Longitudinal Profile			X			X	X	
Bottom Composition			X			X	X	

Key to sources of stress:
Sew = sewage Tox = toxics Ani = animal manure Veg = streamside vegetation removal
Ero = erosion Nut = nutrients Urb = urban runoff AMD = abandoned mine drainage

B.1 Point Source Impact Assessment: Stressors and Recommended Indicators

Parameters/Indicators	Sewage	Toxics
Causes of Stress		
Fecal colif./E. coli Bacteria	X	
Total Phosphorus	X	
Ammonia Nitrogen	X	
Nitrates Nitrogen	X	
Turbidity	X	
Dissolved Oxygen	X	
Biochemical Oxygen Demand	X	
Hardness		X
Aluminum		X
Temperature	X	
Total Dissolved Solids	X	
Total Suspended Solids	X	
Total Residual Chlorine	X	
PH	X	X
Total Alkalinity	X	X
Conductivity	X	
Stream Flow	X	X
Rainfall	X	X
Responses to Stress		
Benthic Macroinvertebrate Assessment	X	X
Benthic Macroinvertebrate Habitat Assessment	X	X

B.2 Non-Point Source Impact Assessment: Stressors and Recommended Indicators

	Sources (Stressors)					
Parameters/Indicators	**Erosion**	**Nutrients**	**Animal Manure**	**Urban Runoff**	**Veg. Removal**	**AMD***
Causes of Stress						
Rainfall	X	X	X	X	X	
River Flow	X	X	X	X	X	X
Fecal colif./E. coli Bacteria			X	X		
Total Phosphorus	X	X	X	X	X	
Total Kjeldahl Nitrogen		X	X	X	X	
Nitrates		X	X	X		
Ammonia			X	X		
Turbidity	X		X	X	X	
Dissolved Oxygen	X	X	X	X	X	
Temperature	X	X	X	X	X	
pH				X		X
Acidity						X
Total Alkalinity				X		X
Conductivity				X		X
Hardness				X		X
Total Iron						X
Manganese						X
Sulfates						X
Aluminum						X
Response Indicators						
Embeddedness	X			X	X	
Channel cross- sections	X			X	X	
Bottom Composition	X			X	X	
Longitudinal Profile	X			X	X	
Intensive Benthic Macroinvertebrate Assessment	X	X	X	X	X	X
Benthic Macroinvertebrate Habitat Assessment	X	X	X	X	X	X

*AMD = abandoned mine drainage

C. Use Support Assessment

Choose indicators for which there are criteria in your state's water quality standards:

Parameters/Indicators	Aquatic Life	Recreation
Fecal colif./E. coli Bacteria		X
Total Phosphorus	X	
Ammonia Nitrogen	X	
Turbidity	X	
Dissolved Oxygen	X	
Hardness	X	
Temperature	X	
Total Residual Chlorine	X	
pH	X	
Total Alkalinity	X	
Conductivity	X	
Stream Flow	X	X
Rainfall	X	X
Benthic Macroinvertebrate Assessment	X	
Benthic Macroinvertebrate Habitat Assessment	X	

Case Study 1

Case Study 2

References:

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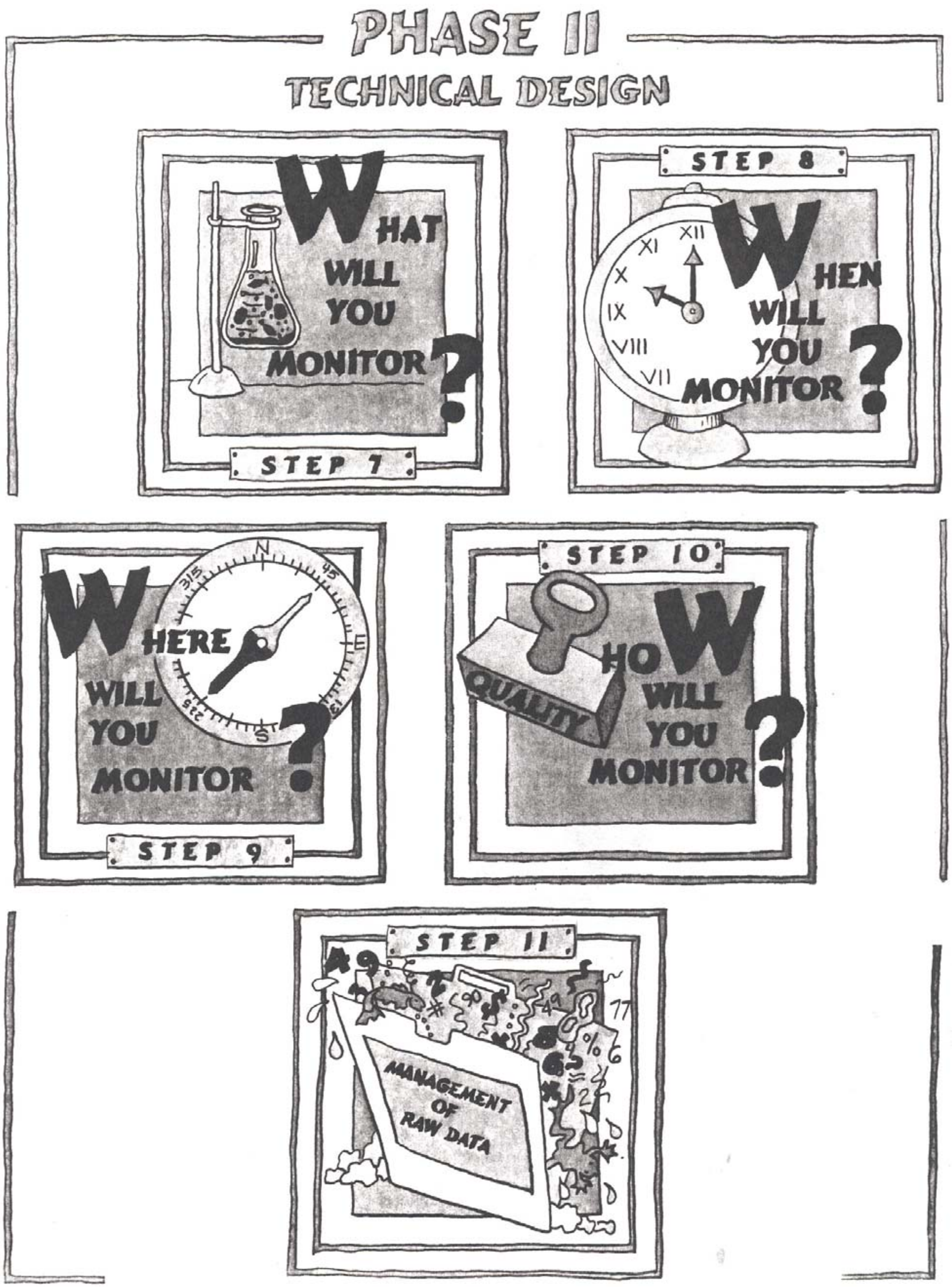
USGS National Field Manual for the Collection of Water Quality Data 2003, book 9 or CD, http://pubs.water.usgs,gov/twri9A/

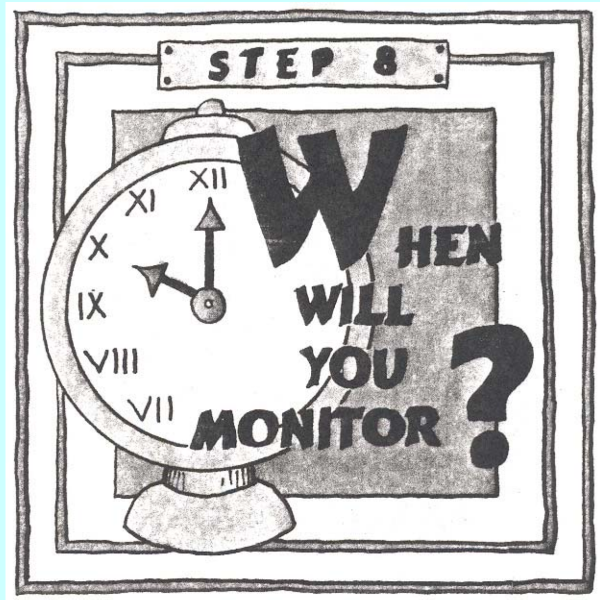
U.S.EPA, Resources for Planning New Data Collections, http://www.epa.gov/quality/rnewdata.html

U.S.EPA, 2002. Guidance on Choosing a Sample Design for Environmental Data Collection, for use in Developing Quality Assurance Plan, EPA/240/R-02/005, EPA QA/G-5S.

Resources:


PHASE II
TECHNICAL DESIGN
WHAT WILL YOU MONITOR?
STEP 7
STEP 8
WHEN WILL YOU MONITOR?
XII
XI
X
IX
VIII
VII
WHERE WILL YOU MONITOR?
STEP 9
STEP 10
HOW WILL YOU MONITOR?
QUALITY
STEP 11
MANAGEMENT OF RAW DATA

Step 8: When Will You Monitor?



"To have a democratic future means actually trying to live in a democratic present. There isn't a point to be involved in activities that are simply means/ends conflicts. You have to find ways in which your idea of hat you're after is on some level achievable in the present."

Colin Greer

About This Step – *This step is designed to accomplish 3 things:*

The focus of this step is to help you select the schedule that will meet your purposes, the needs of your data user, and will be appropriate to your capabilities.

1. Understand the different considerations related to frequency, time of year, time of day, and weather on when you sample.
2. Consider the effects of variability over time on your choice of frequency.
3. Help you decide when and how frequently to sample.

Why Do This Step

In this step, you will put together your sampling schedule. Scheduling depends on the type of assessment you are doing and your specific monitoring question(s). Since the time of day, frequency, and time of year, and weather sampled greatly affect your results, consider each of these when you establish the sampling schedule. This handbook suggests the frequency, time of day and year, and weather conditions for each survey in the following chapters. Work with your technical committee to help devise a sampling schedule that will answer your monitoring questions and match your capabilities.

The parameters and indicators you monitor vary over time. Some vary minute by minute. For example, a "plume" of pollution might be "here and gone," very quickly. Some undergo daily cycles (a.k.a. diurnally), like dissolved oxygen, which responds to photosynthetic activity of plants, which responds to the presence of the sun. Some vary seasonally, like water temperature stratification in a lake or reservoir. Then there are multi-year drought cycles which affect the availability of habitat, as well as water temperature, biological productivity, etc. Storm events can have a profound effect, sometimes long-term, effect on waters.

Human uses and impacts on waters also vary seasonally. For example, in northern climates, swimming is strictly a summer activity, perhaps only in a 3 month window. Seasonal increases in visitors mean more water use and more sewage.

So, this step is critical in your monitoring plan. Once again, it's one of the ways that we are able to distinguish natural variability from that caused by humans.

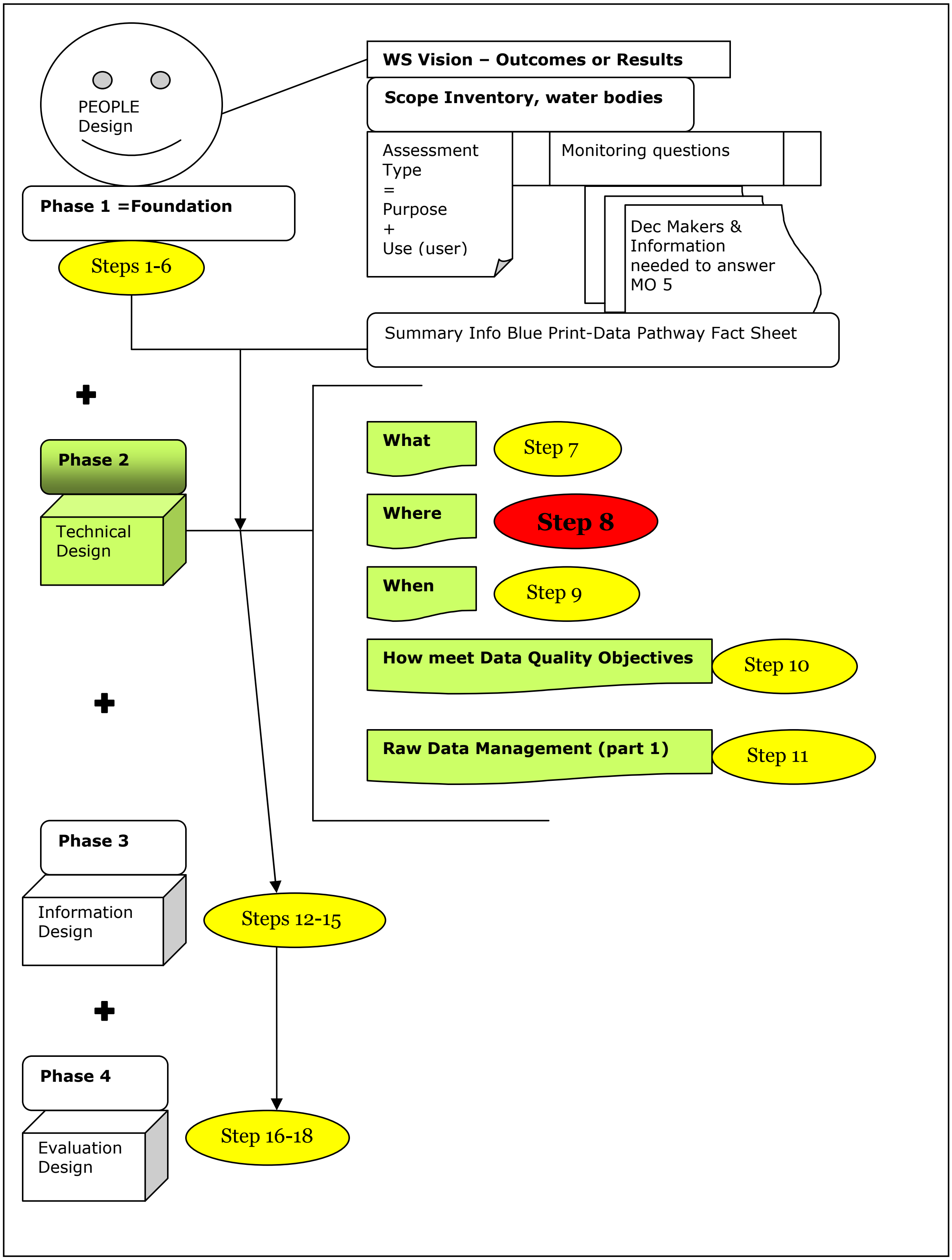
Where are we in the Big Picture Illustration?

Phase 1	Step 1: Share Watershed Vision and Desired Outcomes (Results) Step 2: Scope Inventory (Physical, People and Information) Step 3: Identify Monitoring Reason(s) and Data Use(s) (Assessment Type) Step 4: Develop Monitoring Questions (Refinement of Monitoring Reason) Step 5: Target Decision Makers and Info Needs (Refinement of Data Use) Step 6: Summarize with Information Blue Print-Data Pathway Fact Sheet)
Phase 2	Step 7: What Will You Monitor? **Step 8: When Will You Monitor?** Step 9: Where Will You Monitor? Step 10: How Will You Monitor to Meet Data Quality Objectives? Step 11: Management of Raw Data (Data Management Plan Part 1)
Phase 3	Step 12: Data Summary and Analysis Step 13: Interpretation, Conclusions and Recommendations Step 14: Communicating and Delivery Step 15: Management to Generate Info (Data Management Plan Part 2)
Phase 4	Step 16: Who Will Do What? Task Identification Step 17: Evaluation of Effectiveness (of Plan and Implementation) Step 18: Documentation and Communication (of M & A Plan)

Product (see Figure Phase 2 Product List):

- ✓ A sampling schedule for each parameter or indicator.
- ✓ A list of frequency, time of day and year, and special weather conditions for each parameter/indicator.

Phase 2 Product Illustration:



What Should Be Done Before This Step

A list of indicators (Step 7) for each monitoring question per Assessment Type.

The information listed in the Final Information Blue Print-Data Pathway Fact Sheet, Worksheet 6.3.a in Step 6. This information needs to be provided for every monitoring question per each Assessment Type. The summary sheet should be completed as much as possible but is a starting point. Worksheet 5.4.a and 5.4.a lists the information needed by targeted decision makers and associated data quality objectives. You may also have found valuable information from the Scoping Inventory, especially Worksheet 2.9.a, Worksheet 2.11.a, Worksheet 2.12.a and Worksheet 2.13.a.

- Worksheet 6.3.a is the summary Information Blue Print – Data Pathway Fact Sheet for each monitoring question per Assessment Type, selection of Assessment Type was Worksheet 3.4.a.
- Worksheet 5.4.a and 5.4.b, information needed by targeted decision makers and associated data quality objectives
- Worksheet 2.9.a, Physical Attributes of target water bodies
- Worksheet 2.11.a, Impact Features of target water bodies.
- Worksheet 2.12.a Water body stressor Identification.
- Worksheet 2.13.a Water body Status and/or condition

The assessment type narrows down the parameters you need to consider. Further, tables later in this chapter will help you narrow the field even further.

Steps 1 through 6, Phase 1, do not need to be completed per say, but the information that is a result of those steps are necessary to identify and define to design the monitoring components of what, when, where and how you will gather data. This information is also necessary to plan how the data will generate information, be managed, analyzed, interpreted, delivered to decision makers and evaluated. Information generated in Steps 1-6, Phase 2 are the foundation of every monitoring program.

Thus, ideally you need to have identified a watershed vision and desired outcomes with associated assumptions and external factors. Defined combination of monitoring reasons and uses, we call Assessment types. For each assessment type a list of monitoring questions the data is to answer and how that question will be answered. For each monitoring question, a list of targeted decision makers, their decision, how they make that decision and what information they need to make the decision. Once you have this, you can summarize the results in any format, we suggests the information blueprint we suggests the information blueprint – data pathway fact sheet from Step 6, Worksheet 6.3.a.

Basic Tasks

Basic Tasks are numbered to correlate with the overall 1-18 Steps provided in these guidance modules followed by the basic task sequence step to complete. For example Step 4, basic task 2 would be numbered as Basic Task Step 4.2, Step 3.3 correlates to Step 3, Basic Task 3.

8.1 Identify who will make the decisions about this step and who should be involved in the planning process (they may be different).

8.2 Self Assessment: If you've been monitoring before you've undertaken this process, has the timing and scheduling worked well?

8.3 Decide the Frequency, Time of Year and Time of Day, and Weather

8.4 Update *Inventory Master List* and *Plan.*

8.5 Update *Information Blueprint – Data Pathway Fact Sheet* for each monitoring question.

8.6 Place Products in your *Watershed Monitoring and Assessment Plan*.

8.7 Place your identified gaps and needs regarding this step in the *Action Plan* (what you need to plan to complete this step and or overall monitoring and assessment plan).

Worksheets

Work sheets are listed below. Not all Basic Tasks have an associated work sheet. To simplify completion of products for each step, the worksheets or broken into small subsets of tasks. This requires moving the results of one task into the next task and will seem redundant, especially if completing worksheets by hand. Worksheets are provided in word here for ease of reproducibility. These are a starting point; we encourage you to customize these and reproduced them in an electronic format, in Excel for example, where it is easy to move information from one area to another by cutting and pasting.

Work Sheets are numbered to correlate with Basic Steps and the overall Steps in these guidance modules. Each consecutive work sheet is lettered a, b, c and so forth, preceded by the Basic Task sequence step, preceded by the Step number. For example, Worksheet Step 4.2.a and Step 4.2.b, correlates to Step 4, Basic Task 2, Worksheet a and Worksheet b. In theory worksheet a needs to be completed before worksheet b.

Worksheet 8.2.a **Self Assessment Step 8 Worksheet and Products to be completed Prior to this Step, Part 1 and Part 2.** If you've been monitoring prior to using this planning process, you've got some experience with some of the parameters. In this worksheet, you will evaluate the use and effectiveness of your current parameters.

Worksheet 8.3.a **Sampling Schedule, Frequency, Times, and Weather**

For each parameter/indicator, list the time of year you wish to monitor; how many times you will sample during the year (frequency); the time of day you will collect samples; and the weather conditions you want to capture. Refer back to your Information Blueprint (worksheet 6.1) at your response to Numbers 3: Monitoring Reason; 4: Data Uses; & 6: Type of Info needed by Decision Makers.

The sampling schedule may be different for different indicators. If that is the case, list the indicators that share a common schedule.

Worksheet 8.6.a **Place Products in your** *Watershed Monitoring and Assessment Plan.*

Worksheet 8.7.a **Place your identified gaps and needs regarding this step in the** *Action Plan* **(what you need to plan to complete this step and or overall monitoring and assessment plan).**

How to Do Worksheets

For Sheet 8.2.a Self Assessment Step 8 Worksheet and Products to be completed Prior to this Step. Part 1.

Part 1. Complete the self assessment section of the worksheet to evaluate what you have or what decisions have already been made. This will help you focus on what you need from this step and incorporate valuable existing information or products into this plan.

Part 2. Next, to prepare to complete this step the following, you need to have the following items addressed:

- √ Desired set of outcomes or results that the monitoring and assessment activities will be designed to help achieve
- √ Identified monitoring and assessment activities, specific combinations of a monitoring reason plus an associated data use; we call this an Assessment Type. You may have multiple Assessment Types.
- √ For each Assessment Type, the list of specific monitoring questions the monitoring and assessment will be designed to answer.
- √ For each monitoring question, the targeted decision makers, the type of decisions they will make and the information they need to make them (as specific as possible).
- √ A minimal scoping inventory that identifies the watershed boundary and water bodies you are focusing on (rivers, lakes or wetlands), physical attributes of water bodies (including status, uses, etc.), relevant cultural or historical aspects, existing data sets or monitoring efforts and others in the watershed who either you want to influence or could help you implement.
- √ Technical sample plan including what monitor (indicators, benchmarks, criteria, etc.), where and when monitor, how will meet data quality objectives (methods, how good does the data need to be for decision makers, quality assurance and control measures), and how will manage and verify raw data/information- AT THIS POINT WHAT YOU KNOW, if you don't know it, Phase 2 and 3 help you determine these items.
- √ Set of indicators from Step 7

This is the ideal list, if you do not have any of these, they become a gap or need that should be addressed before any data is collected or analyzed, even if the answers aren't perfect or you don't have a large degree of confidence surrounding them, they should be attempted as the starting point. This is what you are evaluating in this step-your monitoring and assessment plan.

Worksheet 8.2.a Self Assessment Step 8 Worksheet and Products to be completed Prior to this Step. Part 1.

Part 1 Self Assessment of Known Evaluation Products and Processes

1. **Determine if you "have" or "don't have" the item, mark the appropriate box. If you don't have it and determine you don't need it, explain why in the comments document. You may not need to know but perhaps your target decision makers, board or membership might want to know.**

2. **If you have the item "documented", mark that box. If so, list in the comments where, hard copy, chapter in a document, electronic file name and location, etc. The assumption is you value the ultimate goal to document and communicate your M & A plan, activities and results.**

3. **If you have the item, assess the use of it, use the scale below or provide your own answer and comments.**

   Rating Scale for USE:

   0=doesn't exist so use is nil
   1=don't know why would need or understand item
   2=exists, don't know where it is, if it is used, etc. so use is essentially nil
   3=exists and use some of time
   4=exists and use all the time
   5=wish it existed, would use it lots

4. **If you have the item, assess the effectiveness of it, just because something exists or is used does not mean it is effective in its use, use the effectiveness scale below or provide your own answer and comments.**

   Rating Scale for EFFECTIVENESS, assumes material exists:

   0=not effective or functional at all
   1=incomplete (all elements are not there) and some existing parts need revising
   2=incomplete but what is there is okay
   3=complete (all elements are there), some parts okay but need revising
   4=complete and effective

Item	Have	Don't Have	DOC	Assessment of Use (Scale 0-5)	Assessment of value / effectiveness (Scale 0-4)	Comments/Notes
25. Identification of when, frequency for indicators, time of year, day, monitoring reason, etc.?						
Other ?						

*DOC=Documentation, *M & A= Monitoring and Assessment

5. To make this assessment useful, determine what your gaps and needs are regarding this step in order to focus your effort in completing this step.

Worksheet 8.2.a Self Assessment Step 8 Worksheet and Products to be completed Prior to this Step. Part 2.

Part 2 Products to be completed before this step, in order to complete this step, what know from Step 5 and Step 6, Worksheet 6.3.a. Step 7 finalized indicators to this point. If you don't know, you will after this Step.

Item	Response
Desired set of outcomes or results that the monitoring and assessment activities will be designed to help achieve:	
Assessment Types, specific combination of one monitoring reason and data use(r):	
For each Assessment Type, the list of specific monitoring questions:	
For each monitoring question, the targeted decision makers, the type of decisions they will make and the information they need to make them (as specific as possible):	
Watershed(s) and Water bodies of focus:	
Physical attributes of Water bodies (status, use, etc.)	
Existing Data or monitoring efforts:	
Indicators, benchmarks and criteria list (STEP 7):	
List of monitoring locations/rationale:	
List of monitoring frequencies:	
Methods list, list of data quality objectives (methods, how good does the data need to be for decision makers), quality assurance and control measures)	
What you know now about decision makers data-to-information needs, analyses, interpretation and reporting	

For Sheet 8.3.a Sampling Schedule, Frequency, Times, and Weather

Sampling schedule development depends on your specific monitoring question(s) and chosen assessment. Frequency, time of day, time of year, number of years for data collection and weather all influence your results and need to be considered when developing a sampling schedule. The following is a discussion of the importance of each and how to fill in the worksheet. Refer back to the Exercise you completed in Step 3, "Talking to Your Data User," to see which data quality objectives or requirements they may have in regards to the sampling schedule.

1) Parameters

List the same parameters you've been using throughout Step 5 and Step 6.

2) Frequency

How many times should you sample? As with everything else, it depends on the question(s) you have asked, the type of assessment chosen as well as the parameter sampled. If you are trying to establish baseline conditions or monitor impacts, you should collect water samples as often as practical, in as many different conditions, and for as many years as possible. For other types of assessments and parameters, once per year may be enough. For example, you may only need to collect benthic macroinvertebrate samples once per season, or possibly only once per year, since these organisms integrate impacts over relatively long periods of time. There are statistical methods to help you determine how many samples from a given area you should collect to be able to quantify the relationships among the different parameters you are monitoring. These methods are beyond the scope of this guide. For practical purposes, your financial and human resources will probably dictate your sampling frequency. List the dates that parameters (or group of parameters) will be sampled and analyzed.

3) Time of Year

The sun's annual cycle also affects every place on the planet, some more than others. If you want to assess the lowest levels of dissolved oxygen that a river experiences in a year, you will need to take samples during the lowest flow and/or the highest temperature. If you want to know a broad range of oxygen levels that a river experiences in a year, you could take measurements on the same day every month.

Human use and aquatic ecosystems change with the seasons. Water flows, temperatures, chemistry, food sources and the level of biological activity all vary with seasonal cycles. So, in the ideal study, you would sample during all seasons to determine how your ecosystem varies. However, this is not practical, nor necessary, for most volunteer programs.

Consider sampling during critical periods when the ecosystem is under the most stress, such as summer hot, dry periods, to capture worst-case conditions.

Consider sampling during periods when the ecosystem is under the least stress as a benchmark. Consult with your technical committee to determine critical and benchmark sampling periods for your program.

For monitoring that is based on water body use, you need only monitor during the time of year when the use is occurring. For example, to determine beach safety sample during the summer when swimming occurs. You may also want to sample immediately before and after the season in order to establish a benchmark.

4) Time of Day

The sun's daily cycle affects every place on the planet. When the sun comes up, plants start photosynthesizing and producing oxygen. If you are trying to assess the lowest levels of dissolved oxygen that a river experiences in a day, you will need to take samples before the sun comes up. But, if you want to know a broad range of oxygen levels that a river experiences in a 24-hour period, you could take measurements every hour over the entire day. Decide on the time of day you will assess each parameter/indicator.

5) Special Weather Conditions

Because weather can affect a watershed in profound ways, you might also want to assess the impacts of various types (e.g., storm events, droughts, "normal" conditions, relatively hot weather, and relatively cool weather). For example, you might want to assess the sediment load in a river after a big rainstorm. If so, you want to consider getting samples:

- ✓ Before the event begins, to establish background conditions;
- ✓ As water levels rise (and polluted surface runoff enters the stream or lake);
- ✓ As water levels fall after the storm; and
- ✓ When water levels return to pre-storm conditions.

This requires that you have an accurate prediction of when the storm will begin and end; and since weather can occur without much warning, this can be challenging. Decide on any special weather events you will try to capture with your monitoring.

Worksheet 8.3.a Sampling Schedule, Frequency, Times, and Weather

Parameter/ Indicator(s)	Frequency	Time of Year	Time of Day Sampled	Special Weather Conditions

For Sheet 8.6.a Place Products in your *Watershed Monitoring and Assessment Plan*.

- Characterization of when monitoring needs to occur for each indicator. You have a set of indicators for each monitoring question, a set of monitoring questions for each Assessment Type.

Worksheet 8.6.a Add products of Step to *Watershed Monitoring and Assessment Plan.*

If you completed any Steps this Worksheet is cumulative, use that document. If you have not you complete that aspect that is highlighted for your plan documentation. **Italics mean a sub plan that might be attached or live somewhere else, location of document and contact is what would go in the plan.*

I. People Design, Phase 1
   A. Shared Watershed Vision and Desired Outcomes (Step 1)
      1. Logic Model of Desired Outcomes/Results and activities/target audiences to employ to achieve outcomes
   B. Keepers of the M & A Plan (Step 1)
   C. Watershed Boundary (Step 2)
   D. Water bodies of Interest (Step 2)
   E. Scope Inventory Master List* (Step 2)
      1. Physical Inventory * (Step 2)
      2. People Inventory* (Step 2)
      3. Information Inventory* (Step 2)
         a. Existing Monitoring Efforts (Step 2)
         b. Existing Data Sources (Step 2)
      4. Inventory Action Plan* (Step 2)
   F. Assessment Type(s) List – Monitoring Reason + Use (Step 3)
      1. Monitoring Question(s) (Step 4)
      2. Targeted Decision Maker(s) (Step 5)
         a. Information Needs (Step 5)
      3. Information Blue Print – Data Pathway Fact Sheet Per Monitoring Question* (Step 6)

II. Technical Design, Phase 2
   A. What (Indicators, Benchmarks, etc.) and why? (Step 7)
   B. When and why? (Step 8)
   C. Where and why? (Step 9)

D. W(how) will meet data quality objectives? (Step 10)

1. Data quality objectives (Step 5 and 10)
2. Quality Assurance and Control Measures (Quality Assurance and Control Plan)* (Step 10)

E. Data Management for Raw Data (Data Management Plan Part 1)* (Step 11)

III. Information Design, Phase 3

A. Data Summary and Analyses (Step 12)

1. Starting Point (Step 12)
2. Changes (Later)

B. Data Interpretation, Conclusions, Recommendations

1. Starting Point (Step 13)
2. Changes (Later)

C. Communication and Delivery

1. Starting Point (Step 14)
2. Changes (Later)

D. Management Plans to Generate Information (Data Management Plan Part 2)* (Step 15)

IV. Evaluation Design, Phase 4

A. Who Will Do What? (Step 16)

1. Task Identification Matrix (Step 16)
2. Communication Structure and Tools (Step 16)

B. Evaluation Plans (Step 17)

1. Evaluation Plans for M & A Components (Step 17)
2. Evaluation Plans for M & A Implementation (Step 17)
3. Evaluation of inter/intra M & A Activities (Step 17)

C. Documentation and Communication (Step 18)

1. M & A Plan (**this document**, updated Sub documents) (Step 18)
2. Communication and Peer Review Plan (Step 18)
3. Action Plan* (Step 17)

For Sheet 8.7.a **Place your identified gaps and needs regarding this step in the *Action Plan* (what you need to plan to complete this step and or overall monitoring and assessment plan).**

Worksheet 8.7.a **Final *Action Plan* Part 1, Summary:**

If you have completed each Step, or for those you have, you have a cumulated list of gaps and needs related to that Step. Use that same worksheet/document. If you did not complete each Step, look at what each Step is supposed to accomplish and record what your gaps and needs are related to that topic. The goals are to get the gaps and needs in one place to evaluate and prioritize.

Phase 1 Step 1: (completed in Step 1)
Phase 1 Step 2: (completed in Step 2)
Phase 1 Step 3: (completed in Step 3)
Phase 1 Step 4: (completed in Step 4)
Phase 1 Step 5: (completed in Step 5)
Phase 1 Step 6: (completed in Step 6)
Phase 2 Step 7: (completed in Step 7)
Phase 2 Step 8:
Phase 3 and 4 Steps: Will add Action and Needs as complete each Step and at the end prioritize

Background and Content

When and how frequently should you monitor? Here are the main things to think about:

When to Carry Out the Assessment - General Considerations

Think about the information you are trying to collect on each indicator and what you know about the variations over time that might occur at each site and influence your results. Monitoring at the right frequency and time frame can help you understand the short and long-term natural cycles of watershed behavior. With that understanding, you can assess the impact of human activities on those cycles and the watershed response. Once again, the main challenge is to figure out whether changes are due to natural causes (e.g., climate), human causes (e.g., pollution events) or errors in your sampling and analysis. By using the timing of your assessment to account for how the indicator varies, you will make it easier to differentiate the causes of change.

Frequency

How many times should you sample? As with everything else, it depends on the question(s) you have asked, as well as the indicator. If you are trying to establish baseline conditions or monitor impacts, you should collect water samples as often as practical, in as many different conditions, and for as many years as possible. For other types of assessments, once per year is enough. For example, you may only need to collect benthic macroinvertebrate samples once per season, or possibly only once per year, since these organisms integrate impacts over relatively long periods of time (months). There are statistical methods to help you determine how many samples from a given area you should collect to be able to quantify the relationships among the different indicators you are monitoring. These methods are beyond the scope of this handbook. For practical purposes, your financial and human resources will probably dictate your sampling frequency. List the dates that this indicator (or group of indicators) will be sampled and analyzed.

Time of Day

The sun's daily cycle affects every place on the planet. When the sun comes up, the plants start photosynthesizing and producing oxygen for all life. So if you are trying to assess the lowest levels of dissolved oxygen that a river experiences in a day, you will need to take samples before the sun comes up. But, if you want to know a broad range of oxygen levels that a river experiences in a 24-hour period, you could take measurements every hour over the entire day. Decide on the time of day you will assess every indicator.

Time of Year

The sun's annual cycle also affects every place on the planet-some more variably than others. If you want to assess the lowest levels of dissolved oxygen that a river experiences in a year, you will need to take samples during the lowest flow and/or the highest temperature. If you want to know a broad range of oxygen levels that a river experiences in a year, you could take measurements on the same day every month.

Human use and aquatic ecosystems change with the seasons. Water flows, temperatures, chemistry, food sources and the level of biological activity all vary with seasonal cycles. So, in the ideal study, you would sample during all seasons to determine how your ecosystem varies. However, this is not practical, nor necessary, for most volunteer programs.

- Consider sampling during critical periods when the ecosystem is under the most stress (such as summer hot, dry periods) to capture worst-case conditions.
- Consider sampling during periods when the ecosystem is under the least stress as a benchmark. Consult with your technical committee to determine critical and benchmark sampling periods for your program.
- For monitoring that is based on the use of the water body, you need only monitor during the time of year when the use is occurring (for example, during the summer for swimming), though you may want to sample immediately before and after the season in order to establish a benchmark.

Decide on the time of year you will assess every indicator.

Multiple Years

Because no two years are exactly alike, the best assessment of watershed health includes many years of information. This information will give you a better understanding of the range of conditions that a watershed experiences, from droughts to floods. The lowest dissolved oxygen levels between years might vary considerably, if water levels fluctuate dramatically. Decide on the number of years you plan to collect information.

Weather

Because weather can affect a watershed in profound ways, you might also want to assess the impacts of various types (e.g., storm events, droughts, "normal" conditions, relatively hot weather, and relatively cool weather). For example, you might want to assess the sediment load in a river after a big rainstorm. If so, you want to consider getting samples –

- Before the event begins, to establish background conditions;
- As water levels rise (and polluted surface runoff enters the stream or lake);
- As water levels fall after the storm; and
- When water levels return to pre-storm conditions.

This requires that you have an accurate prediction of when the storm will begin and end; and since weather can occur without much warning, this can be challenging. Decide on any special weather events you will try to capture with your monitoring.

Human Use and Impacts

The use of water and watersheds by humans also varies over time-some of which fluctuate with regularity and others do not. You might want to consider the following uses and the influence of their timing on your assessment:

- Ceremonies

- Hunting
- Fishing
- Dam Releases
- Water Withdrawals for Things such as:
- Irrigation
- Snow-making
- Recreational Tourism
- Farming

Variability

Watershed conditions vary over periods of time, from hours to years.

- **Natural variability**: Watershed conditions change over the course of a day, seasonally and annually in response to sunlight, precipitation and other natural cycles. The response to these natural cycles differs dramatically depending on the indicators you are measuring. For example, dissolved oxygen varies hourly, especially at sunrise and at dusk. On the other hand, aquatic life integrates changes in conditions in time periods ranging from a matter of hours (say from a flood) to multiple years (say from a multi-year drought). There may also be dramatic differences in different regions, say between temperate, wet New England to the arid southwest.
- **Human-induced variability**: Human activities can cause impacts that range from minutes to years. For example, a toxic spill might kill critters almost instantly. On the other hand, land development may gradually change the way water behaves as impervious surfaces gradually reduce the ability of the land to soak up water. As with natural variability, this varies with region.
- **Sampling and analysis variability**: Carrying out your assessment may also increase the probability of errors. For example, sampling bottom-dwelling critters or sediment during high flows can be very challenging.

Assessment Approach

Comprehensive

A comprehensive assessment should include a range of samples for each indicator that represent the various cycles of time and sources of variability described above.

Targeted

A targeted assessment is generally focused on a particular process or location that will dictate the frequency of sampling (e.g., sampling below a sewage discharge before, during and after a rain event). However, if you don't have a basic understanding of how a process or conditions at a location vary, you might need to start with a more comprehensive approach in order to learn.

Recommendations for Each Type of Assessment

Remember how we said this process isn't totally linear? As you think about recommendations for each kind of assessment, make note of your possible Data Quality Objectives (Step 10). Specifically, in Step 8, consider the following:

Completeness: How many measurement samples will you need for a complete data set? You need to consider the overall number of samples needed, as well as the number needed at particular sites and under any different conditions dictated by your study question.

Representativeness: How many samples will you collect, and how frequently will you collect them to ensure that they represent the actual environmental condition or population you are sampling? This is important because you have practical limitations of how often you can sample (i.e. you can't consistently sample a site every second, every 60 seconds, or even every 10 minutes).

- The appropriateness of your sampling site selection for describing the general characteristics of the water body and specific impacts.
- The appropriateness of the location of the sample collection point: spatial location (mid-stream, mid-lake, etc.), sampling depth, number of sites, etc.
- The appropriateness of the parameters to the type of impact. Later sections evaluate these issues in greater detail and should be consistent with the statement here.

Then, apply that to specific recommendations for each kind of assessment:

Condition and Trend Assessment

Water Sampling and Analysis:

- **Frequency**: sample at least two or three times per month, during the monitoring season.
- **Time of day**: sample during critical periods of the day for those indicators that fluctuate daily -- early morning for dissolved oxygen, late afternoon for temperature. (Also, consider 24-hour studies for these indicators to determine daily variability).
- **Time of year**: Sample during critical periods of ecosystem stress - such as summer low flow and high air temperature conditions - and less stressful periods such as mid-late spring to get a sense of seasonal variation.
- **Weather**: a variety of weather conditions: storm events, droughts, "normal" conditions, relatively hot weather, relatively cool weather, etc.

Benthic Macroinvertebrate Sampling and Analysis and Habitat Assessment

- **Frequency and time of year**: sample at least once per year, once in the mid-spring or once in late summer or early fall (before leaf fall).
- **Time of day and** weather: Not a consideration, though high flows should be avoided.

Stream Channel Measurements (embeddedness, cross-sections, longitudinal profiles, bottom composition)

- **Frequency and time of year**: sample at least once per year during consistent flows and after bank full flows.
- **Time of day and weather**: Not a consideration, though measuring during dangerously high flows should be avoided.

Point Source Impact Assessment

Water Sampling and Analysis:

- **Frequency**: Sample at least once per month during the chosen time of year, both during storms and during dry weather. Sampling must be conducted over a minimum of one year.
- **Time of day**: Runoff event sampling is challenging. Ideally, samples should be collected at regular intervals before, during and after the storm event. This is likely impractical, so we recommend three samplings for each storm event: at the onset of the rain event (to establish baseline conditions), during (to catch the "first flush" and establish conditions during rising flows), and after (to establish conditions during high or falling flows).
- **Time of year**: Sample during critical periods of ecosystem stress, such as summer, and less stressful periods, such as mid-late spring.
- **Weather**: A variety of weather conditions: storm events, droughts, "normal" conditions, relatively hot weather, relatively cool weather, etc.

Benthic Macroinvertebrate Sampling and Analysis and Habitat Assessment

- **Frequency and time of year**: Sample at least twice per year, once in the mid-spring and once in late summer or early fall (before leaf fall).
- **Time of day and weather**: Not a consideration, though high flows should be avoided.

Field Measurements of Flow and Channel Shape:

- **Frequency and time of year**: Measure flows at least as frequently as water sampling, daily if possible. Measure channel characteristics in association with runoff events (see below).
- **Time of day**: Not a consideration.
- **Weather**: Measure channel characteristics before and after major storm events.

Non-Point Source Impact Assessment

Water Sampling and Analysis:

- **Frequency**: Sample at least two or three times per month during the chosen time of year, both during storms and during dry weather. Sampling must be conducted over a minimum of one year.
- **Time of day**: Runoff event sampling is challenging. Ideally, samples should be collected at regular intervals before, during and after the storm event. This is likely impractical, so we recommend three samplings for each storm event: at the onset of the rain event (to

establish baseline conditions), during (to catch the "first flush" and establish conditions during rising flows), and after (to establish conditions during high or falling flows).

- **Time of year**: Sample during critical periods of ecosystem stress, such as summer, and less stressful periods, such as mid-late spring.
- **Weather**: A variety of weather conditions: storm events, droughts, "normal" conditions, relatively hot weather, relatively cool weather, etc.

Benthic Macroinvertebrate Sampling and Analysis and Habitat Assessment

- **Frequency and time of year**: Sample at least twice per year, November through May.
- **Time of day and weather**: Not a consideration, though high flows should be avoided.

Field Measurements of Flow and Channel Shape

- **Frequency and time of year**: Measure flows at least as frequently as water sampling, daily if possible. Measure channel characteristics in association with runoff events (see below)
- **Time of day**: Not a consideration.
- **Weather**: Measure channel characteristics before and after major storm events.

Use Support Assessment

Water Sampling and Analysis:

- **Frequency**: sample at least once per month, during the monitoring season. Sampling must be conducted over a minimum of one year.
- **Time of day**: sample during critical periods of the day for those indicators that fluctuate daily . For example, dissolved oxygen and temperature are both typically lowest at sunup and highest in mid-day. Critical (low) levels of DO for fish will likely occur in the early morning. Critical (high) temperature levels for fish will likely occur in mid-afternoon.
- **Time of year**: for assessing dissolved oxygen suitability for fish, sample during critical periods of stress – such as summer low flow and high air temperature conditions – and less stressful periods such as mid-late spring to get a sense of seasonal variation. Also, try to sample during spawning and rearing periods.
- **Weather**: a variety of weather conditions: storm events, droughts, "normal" conditions, relatively hot weather, relatively cool weather, etc.

Benthic Macroinvertebrate Sampling and Analysis and Habitat Assessment

- **Frequency and time of year**: sample at least once per year, from November through May.
- **Time of day and weather**: not a consideration, though high flows should be avoided.

Effectiveness Assessment

Water Sampling and Analysis:

- Frequency

- Time of day
- Time of year
- Weather

Benthic Macroinvertebrate Sampling and Analysis and Habitat Assessment

- Frequency and time of year
- Time of day and weather

Field Measurements of Flow and Channel Shape

- Frequency and time of year
- Time of day
- Weather

Case Study 1

Case Study 2

References

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Harrelson, Cheryl C., 1994. *Stream Channel Reference Sites: An Illustrated Guide To Field Technique*, U.S. Forest Service General Technical Report RM-245, Fort Collins, CO.

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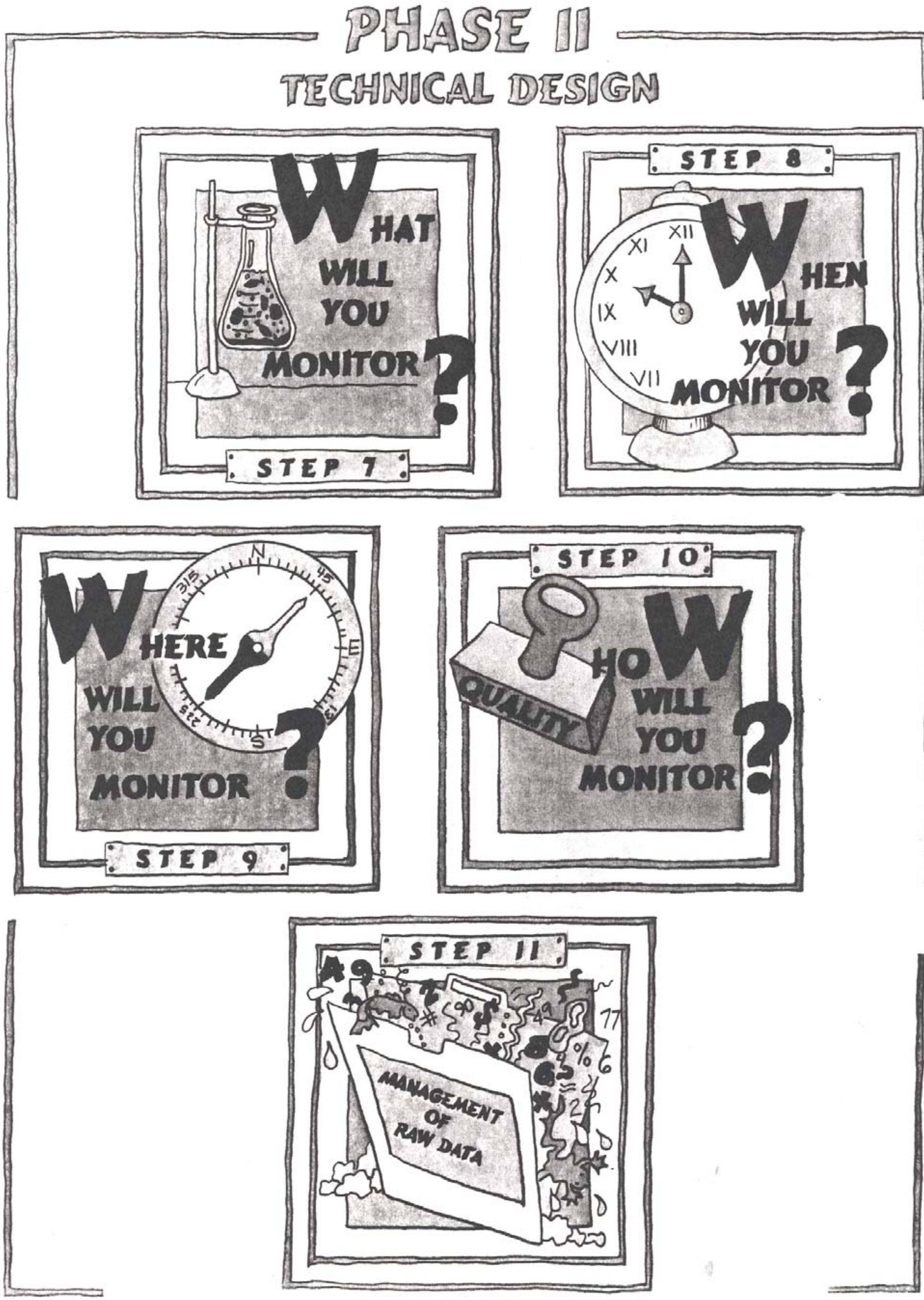
U.S.EPA, *Selecting a sample design, where/when factors for analyses*, quick check list, http://www.epa.gov/quality/qksampl.html

Resources


PHASE II
TECHNICAL DESIGN
WHAT WILL YOU MONITOR?
STEP 7
STEP 8
WHEN WILL YOU MONITOR?
WHERE WILL YOU MONITOR?
STEP 9
STEP 10
QUALITY
HOW WILL YOU MONITOR?
STEP 11
MANAGEMENT OF RAW DATA

Step 9: Where Will You Monitor?

"I am an agitator, and an agitator is the center post in a washing machine that gets the dirt out."

Jim Hightower

About This Step – *This step is designed to accomplish 3 things:*

1. Understand the different considerations related to choosing sites.
2. Consider the effects of scale and variability on your choice of sites.
3. Help you decide when and how frequently to sample.

The focus of this step is to help you select the sampling locations that will meet your purposes, the needs of your data user, and will be appropriate to your capabilities.

Why Do This Step

In Step 1, you identified your waters of interest. Now it's time to identify the specific locations where you will collect monitoring information. First, refer to the following chapters for the site selection considerations for each type of assessment you selected.

Consult with your technical committee to help you refine these considerations into criteria you will use to select your sites to answer your questions. Next, use a topographic map to do a preliminary selection of sites that appear to meet your criteria. Determine how many of these sites you can monitor. Consider safety, accessibility, your human resources and how many samples you can analyze. Field check each site for accessibility, representativeness, safety and appropriateness. Record directions to the site, a brief description of the site and other relevant information in a site log notebook. Get *landowner permission to use sites on private property*. Drop the sites where you cannot obtain permission. Finalize your list of sampling sites. Photograph each site at the sample collection point and place the site description and the photograph in a loose-leaf binder for permanent archiving. Locate each final site on your topographic map. Finally, identify the laboratory where the analysis of samples will be performed.

As described earlier, a larger assessment area typically means there will be a greater amount of variability to account for in your data analysis. This means that it's especially important to understand the natural changes in a watershed. Site selection may be the most important tool you have to distinguish among the 3 types of variability.

This step will get you to clarify why each site was chosen and what you hope the results will tell you about the river or lake.

The parameters and indicators you monitor vary over space. We've mentioned natural changes that can happen upstream to downstream as a result of changing gradient, forest cover, altitude, etc. Properly locating your sampling sites can reveal the role of the changing landscape and the character of the eco-region, in causing natural variability. For example, the same stream can change dramatically as it comes down out of its origin in the arctic alpine meadows of the Rockies, through tree line, thickly forested areas, canyons, and finally into the desert. You really can't use the artic alpine stream as a reference condition for the desert part.

This step will get you to think about different types of sites, each of which represents a whole class of sites (e.g. mountain streams, oligotrophic lakes), and then by function (e.g. reference sites, impact sites).

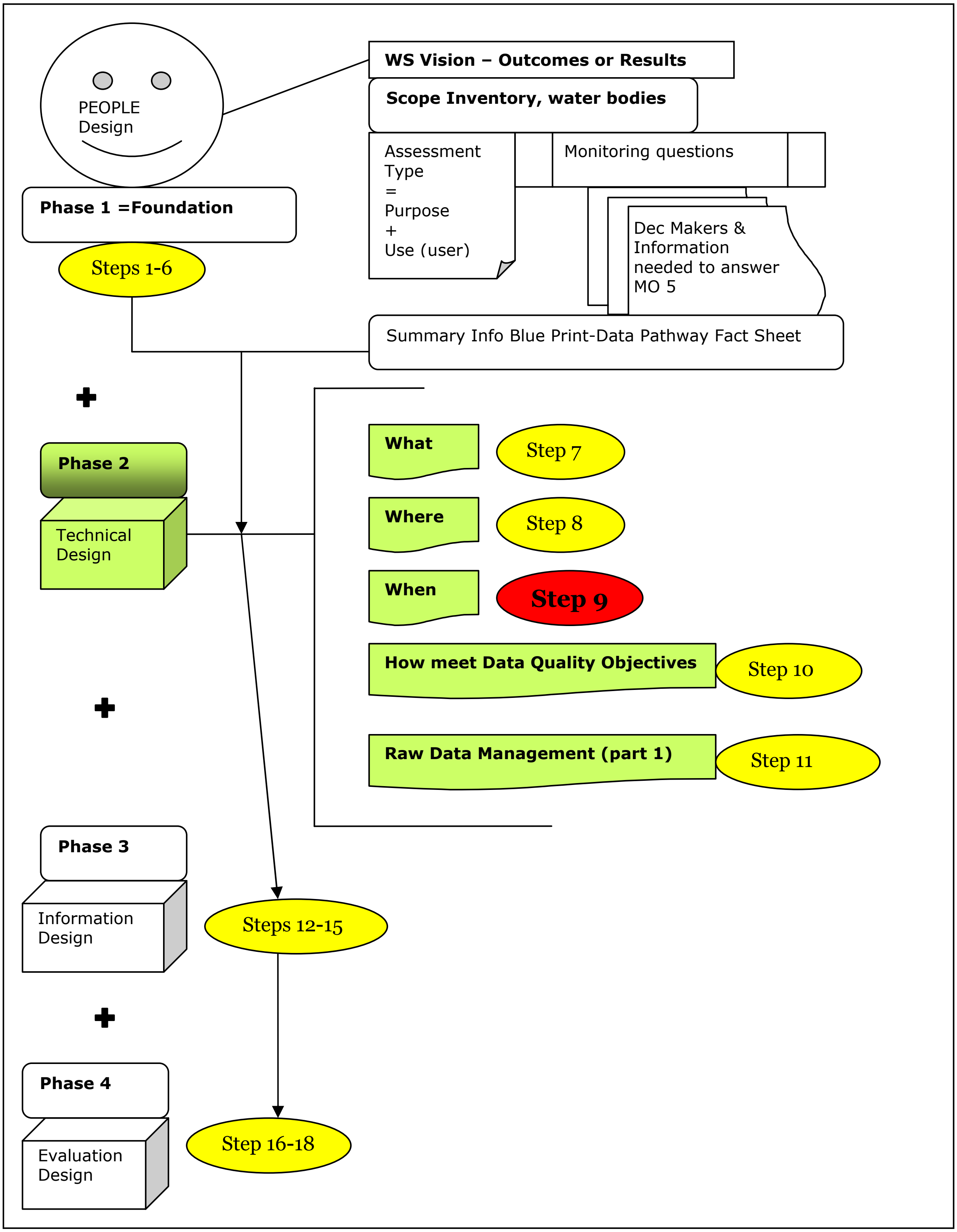
Where are we in the Big Picture Illustration?

Phase 1	Step 1: Share Watershed Vision and Desired Outcomes (Results) Step 2: Scope Inventory (Physical, People and Information) Step 3: Identify Monitoring Reason(s) and Data Use(s) (Assessment Type) Step 4: Develop Monitoring Questions (Refinement of Monitoring Reason) Step 5: Target Decision Makers and Info Needs (Refinement of Data Use) Step 6: Summarize with Information Blue Print-Data Pathway Fact Sheet)
Phase 2	Step 7: What Will You Monitor? Step 8: When Will You Monitor? **Step 9: Where Will You Monitor?** Step 10: How Will You Monitor to Meet Data Quality Objectives? Step 11: Management of Raw Data (Data Management Plan Part 1)
Phase 3	Step 12: Data Summary and Analysis Step 13: Interpretation, Conclusions and Recommendations Step 14: Communicating and Delivery Step 15: Management to Generate Info (Data Management Plan Part 2)
Phase 4	Step 16: Who Will Do What? Task Identification Step 17: Evaluation of Effectiveness (of Plan and Implementation) Step 18: Documentation and Communication (of M & A Plan)

Product (see Figure Phase 2 Product List):

A list of sampling stations, which includes type of site and purpose for each one that will answer monitoring questions and achieve desired outcomes.

Phase 2 Product Illustration:



What Should Be Done Before This Step

A list of indicators (Step 7) for each monitoring question per Assessment Type, a characterization of monitoring frequency for each indicator (Step 8).

The information listed in the Final Information Blue Print-Data Pathway Fact Sheet, Worksheet 6.3.a in Step 6. This information needs to be provided for every monitoring question per each Assessment Type. The summary sheet should be completed as much as possible but is a starting point. Worksheet 5.4.a and 5.4.a lists the information needed by targeted decision makers and associated data quality objectives. You may also have found valuable information from the Scoping Inventory, especially Worksheet 2.9.a, Worksheet 2.11.a, Worksheet 2.12.a and Worksheet 2.13.a.

- Worksheet 6.3.a is the summary Information Blue Print – Data Pathway Fact Sheet for each monitoring question per Assessment Type, selection of Assessment Type was Worksheet 3.4.a.
- Worksheet 5.4.a and 5.4.b, information needed by targeted decision makers and associated data quality objectives
- Worksheet 2.9.a, Physical Attributes of target water bodies
- Worksheet 2.11.a, Impact Features of target water bodies.
- Worksheet 2.12.a Water body stressor Identification.
- Worksheet 2.13.a Water body Status and/or condition

The assessment type narrows down the parameters you need to consider. Further, tables later in this chapter will help you narrow the field even further.

Steps 1 through 6, Phase 1, do not need to be completed per say, but the information that is a result of those steps are necessary to identify and define to design the monitoring components of what, when, where and how you will gather data. This information is also necessary to plan how the data will generate information, be managed, analyzed, interpreted, delivered to decision makers and evaluated. Information generated in Steps 1-6, Phase 2 are the foundation of every monitoring program.

Thus, ideally you need to have identified a watershed vision and desired outcomes with associated assumptions and external factors. Defined combination of monitoring reasons and uses, we call Assessment types. For each assessment type a list of monitoring questions the data is to answer and how that question will be answered. For each monitoring question, a list of targeted decision makers, their decision, how they make that decision and what information they need to make the decision. Once you have this, you can summarize the results in any format, we suggests the information blueprint we suggests the information blueprint – data pathway fact sheet from Step 6, Worksheet 6.3.a.

Basic Tasks

Basic Tasks are numbered to correlate with the overall 1-18 Steps provided in these guidance modules followed by the basic task sequence step to complete. For example Step 4, basic task 2 would be numbered as Basic Task Step 4.2, Step 3.3 correlates to Step 3, Basic Task 3.

9.1 Identify who will make the decisions about this step and who should be involved in the planning process (they may be different).

9.2 Self Assessment: If you've been monitoring before you've undertaken this process, have the parameters you've measured worked well?

9.3 Identify Sampling sites.

9.4 Describe where at each site samples will be collected

9.5 Update *Inventory Master List* and *Plan.*

9.6 Update *Information Blueprint – Data Pathway Fact Sheet* for each monitoring question.

9.7 Place Products in your *Watershed Monitoring and Assessment Plan*.

9.8 Place your identified gaps and needs regarding this step in the *Action Plan* (what you need to plan to complete this step and or overall monitoring and assessment plan).

Worksheets

Work sheets are listed below. Not all Basic Tasks have an associated work sheet. To simplify completion of products for each step, the worksheets or broken into small subsets of tasks. This requires moving the results of one task into the next task and will seem redundant, especially if completing worksheets by hand. Worksheets are provided in word here for ease of reproducibility. These are a starting point; we encourage you to customize these and reproduced them in an electronic format, in Excel for example, where it is easy to move information from one area to another by cutting and pasting.

Work Sheets are numbered to correlate with Basic Steps and the overall Steps in these guidance modules. Each consecutive work sheet is lettered a, b, c and so forth, preceded by the Basic Task sequence step, preceded by the Step number. For example, Worksheet Step 4.2.a and Step 4.2.b, correlates to Step 4, Basic Task 2, Worksheet a and Worksheet b. In theory worksheet a needs to be completed before worksheet b.

Worksheet 9.2.a **Self Assessment Step 9 Worksheet and Products to be completed Prior to this Step, Part 1 and Part 2.** If you've been monitoring prior to using this planning process, you've got some experience with some of the parameters. In this worksheet, you will evaluate the use and effectiveness of your current parameters.

Worksheet 9.3.a **Sampling Site List**

Worksheet 9.4.a **Describe where samples will be taken at each site**

Worksheet 9.7.a **Place Products in your** *Watershed Monitoring and Assessment Plan.*

Worksheet 9.8.a **Place your identified gaps and needs regarding this step in the** *Action Plan* **(what you need to plan to complete this step and or overall monitoring and assessment plan).**

How To Do Worksheets

For Sheet 9.2.a Self Assessment Step 9 Worksheet and Products to be completed Prior to this Step. Part 1.

Part 1. Complete the self assessment section of the worksheet to evaluate what you have or what decisions have already been made. This will help you focus on what you need from this step and incorporate valuable existing information or products into this plan.

Part 2. Next, to prepare to complete this step the following, you need to have the following items addressed:

- √ Desired set of outcomes or results that the monitoring and assessment activities will be designed to help achieve
- √ Identified monitoring and assessment activities, specific combinations of a monitoring reason plus an associated data use; we call this an Assessment Type. You may have multiple Assessment Types.
- √ For each Assessment Type, the list of specific monitoring questions the monitoring and assessment will be designed to answer.
- √ For each monitoring question, the targeted decision makers, the type of decisions they will make and the information they need to make them (as specific as possible).
- √ A minimal scoping inventory that identifies the watershed boundary and water bodies you are focusing on (rivers, lakes or wetlands), physical attributes of water bodies (including status, uses, etc.), relevant cultural or historical aspects, existing data sets or monitoring efforts and others in the watershed who either you want to influence or could help you implement.
- √ Technical sample plan including what monitor (indicators, benchmarks, criteria, etc.), where and when monitor, how will meet data quality objectives (methods, how good does the data need to be for decision makers, quality assurance and control measures), and how will manage and verify raw data/information- AT THIS POINT WHAT YOU KNOW, if you don't know it, Phase 2 and 3 help you determine these items.
- √ Set of indicators from Step 7 and frequency characterization from Step 8

This is the ideal list, if you do not have any of these, they become a gap or need that should be addressed before any data is collected or analyzed, even if the answers aren't perfect or you don't have a large degree of confidence surrounding them, they should be attempted as the starting point. This is what you are evaluating in this step-your monitoring and assessment plan.

Worksheet 9.2.a Self Assessment Step 9 Worksheet and Products to be completed Prior to this Step.

Part 1 Self Assessment of Known Evaluation Products and Processes

1. **Determine if you "have" or "don't have" the item, mark the appropriate box. If you don't have it and determine you don't need it, explain why in the comments document. You may not need to know but perhaps your target decision makers, board or membership might want to know.**

2. **If you have the item "documented", mark that box. If so, list in the comments where, hard copy, chapter in a document, electronic file name and location, etc. The assumption is you value the ultimate goal to document and communicate your M & A plan, activities and results.**

3. **If you have the item, assess the use of it, use the scale below or provide your own answer and comments.**

Rating Scale for USE:
0=doesn't exist so use is nil
1=don't know why would need or understand item
2=exists, don't know where it is, if it is used, etc. so use is essentially nil
3=exists and use some of time
4=exists and use all the time
5=wish it existed, would use it lots

4. **If you have the item, assess the effectiveness of it, just because something exists or is used does not mean it is effective in its use, use the effectiveness scale below or provide your own answer and comments.**

Rating Scale for EFFECTIVENESS, assumes material exists:
0=not effective or functional at all
1=incomplete (all elements are not there) and some existing parts need revising
2=incomplete but what is there is okay
3=complete (all elements are there), some parts okay but need revising
4=complete and effective

Item	Have	Don't Have	DOC	Assessment of Use (Scale 0-5)	Assessment of value / effectiveness (Scale 0-4)	Comments/Notes
26. Identification of where data/information is needed, water bodies, station location, up/down, pre/post, etc.?						
Other?						

*DOC=Documentation, *M & A= Monitoring and Assessment

5. To make this assessment useful, determine what your gaps and needs are regarding this step in order to focus your effort in completing this step.

Worksheet 9.2.a Self Assessment Step 9 Worksheet and Products to be completed Prior to this Step. Part 2.

Part 2 Products to be completed before this step, in order to complete this step, what know from Step 5 and Step 6, Worksheet 6.3.a. Step 7 finalized indicators to this point. If you don't know, you will after this Step.

Item	Response
Desired set of outcomes or results that the monitoring and assessment activities will be designed to help achieve:	
Assessment Types, specific combination of one monitoring reason and data use(r):	
For each Assessment Type, the list of specific monitoring questions:	
For each monitoring question, the targeted decision makers, the type of decisions they will make and the information they need to make them (as specific as possible):	
Watershed(s) and Water bodies of focus:	
Physical attributes of Water bodies (status, use, etc.)	
Existing Data or monitoring efforts:	
Indicators, benchmarks and criteria list (STEP 7):	
For each indicator, when monitor? (STEP 8):	
List of monitoring locations/rationale:	
List of monitoring frequencies:	
Methods list, list of data quality objectives (methods, how good does the data need to be for decision makers), quality assurance and control measures)	
What you know now about decision makers data-to-information needs, analyses, interpretation and reporting	

For Sheet 9.3.a Sampling Site List

This table is your list of all your sampling locations chosen through a site selection process. As needed, refer back to your Information Blueprint (Worksheet 6.3.a) at your response to Numbers 4: Data Uses, and Number 6: Type of Info needed by Decision Makers.

When researchers select sampling locations they will monitor, they may use complex statistical approaches that are geared to producing sites that are representative of the area being monitored. Describing these methods is beyond the scope of this workbook. However, we describe types of sampling sites below and site selection considerations for each of the surveys in the chapters that follow.

- **Site Number**

  Assign a unique number to each site. There are various site numbering schemes available. Pick one that allows you to easily add sites. In general, a site numbering system based on the name of a stream and the distance of the site from the mouth seems to work best. An example for the Snake River might be SnaR085. SnaR stands for Snake River and "085" means the site is located 85 miles from the mouth of the Snake River.

- **Brief Description of Location**

  Include a brief phrase that describes the location of the site. Also, include any state codes for the segment that includes the site.

- **How and Where the Site Will Be Sampled**

  Describe the sampling technique and where the sample will be taken at the site. For example: "grab sample taken from boat in mid-channel." For water sampling, the two main issues are where in the water column and where across the stream you will collect samples.

- **Type of site**

  Using the list of different types of sites (see Background section below), write the type(s) of habitat found at each site. For the most part, we recommend sampling the cobble-bottom micro-habitats (an area within a riffle that has cobble in the substrate) at riffle, largely because they contain the most abundant and diverse communities. However, if riffles and cobble are not available, rock baskets can be suspended in the water column in "run" type macro-habitats. Other microhabitats can be sampled directly, including: aquatic vegetation, large woody debris, leaf packs and root wads along the banks. A similar habitat should be sampled at each station for meaningful comparison.

- **Indicators that will be sampled at each site:**

  Include what specific parameters will be monitored. Refer back to your list of parameters and indicators completed in worksheet 7.2.

Worksheet 9.3.a. Sampling Site List

Site #	Brief Description of Location (Code for Segment, if any)	How and Where the Site Will Be Sampled	Type of Site (Include Habitat Type)	Parameters/Indicators

For Sheet 9.4.a Describe where samples will be taken at each site

- **Where In the Water Column (what depth)?**

In streams, the main thing to consider is whether the water is evenly mixed from surface to bottom. If not, water quality may vary quite a bit at different depths, due to different water velocities. This is especially true for sediment in deep rivers with smooth bottoms. In this case, the different velocities at different depths would each be capable of carrying certain size particles in certain quantities. In these rivers, you may need to collect samples from multiple depths, depending on the indicator you are monitoring. Otherwise, a sample collected about eight inches below the surface may be sufficient. In shallow, high velocity, turbulent streams, we generally make the assumption that the water mixes fairly evenly from top to bottom. In these streams, water samples should be about half way between the surface and the bottom.

Lakes are usually not homogenous throughout the water column. Generally, lakes stratify into three layers determined by the different density of water at different temperatures. These are the epilimnion, the metalimnion and the hypolimnion, from surface to bottom. So, for some indicators, such as dissolved oxygen and nutrients, samples should be collected at regular intervals (usually every meter or so) down through each layer. These samples may be analyzed separately if your questions concern conditions at each layer. If not, the samples may be combined into a depth-integrated sample.

- **Where Across the Transect?**

Water, habitat and aquatic communities can also vary significantly across the stream or lake transect (across the water) due to uneven mixing of the indicator you are measuring. So, where you decide to collect the sample is important. In streams, we recommend that water samples and most measurements be collected in the main stream current and away from the banks, at sites where the stream seems to be evenly mixed. Uneven mixing across streams occurs where tributaries join, downstream of structures such as dams or diversions, and at meanders. In these cases, you may want to collect samples at regular intervals across the stream. These samples can be analyzed separately, if you wish to measure the variation across the stream, or combined into an integrated sample to "average" the variation. Lakes vary even more dramatically than streams. This is especially true when the lake has many bays and coves. We recommend the deepest part of the main lake and bays for overall characterization and near shore areas for water use assessment and aquatic weed monitoring.

Worksheet 9.4.a. Describe where at each site samples will be collected

Indicator	Where In the Water Column?	Where Across Transect?

For Sheet 9.7.a Place Products in your *Watershed Monitoring and Assessment Plan*.

- Site locations for each monitoring question/Assessment Type, associated indicators and frequencies, including location description and specifically where at each site samples will be collected

Worksheet 9.7.a Add products of Step to *Watershed Monitoring and Assessment Plan.*

If you completed any Steps this Worksheet is cumulative, use that document. If you have not you complete that aspect that is highlighted for your plan documentation. **Italics mean a sub plan that might be attached or live somewhere else, location of document and contact is what would go in the plan.*

I. People Design, Phase 1

   A. Shared Watershed Vision and Desired Outcomes (Step 1)

      1. Logic Model of Desired Outcomes/Results and activities/target audiences to employ to achieve outcomes

   B. Keepers of the M & A Plan (Step 1)

   C. Watershed Boundary (Step 2)

   D. Water bodies of Interest (Step 2)

   E. Scope Inventory Master List* (Step 2)

      1. Physical Inventory * (Step 2)

      2. People Inventory* (Step 2)

      3. Information Inventory* (Step 2)

         a. Existing Monitoring Efforts (Step 2)

         b. Existing Data Sources (Step 2)

      4. Inventory Action Plan* (Step 2)

   F. Assessment Type(s) List – Monitoring Reason + Use (Step 3)

      1. Monitoring Question(s) (Step 4)

      2. Targeted Decision Maker(s) (Step 5)

         a. Information Needs (Step 5)

      3. Information Blue Print – Data Pathway Fact Sheet Per Monitoring Question* (Step 6)

II. Technical Design, Phase 2

   A. What (Indicators, Benchmarks, etc.) and why? (Step 7)

   B. When and why? (Step 8)

   C. Where and why? (Step 9)

D. W(how) will meet data quality objectives? (Step 10)

1. Data quality objectives (Step 5 and 10)
2. Quality Assurance and Control Measures (Quality Assurance and Control Plan)* (Step 10)

E. Data Management for Raw Data (Data Management Plan Part 1)* (Step 11)

III. Information Design, Phase 3

A. Data Summary and Analyses (Step 12)

1. Starting Point (Step 12)
2. Changes (Later)

B. Data Interpretation, Conclusions, Recommendations

1. Starting Point (Step 13)
2. Changes (Later)

C. Communication and Delivery

1. Starting Point (Step 14)
2. Changes (Later)

D. Management Plans to Generate Information (Data Management Plan Part 2)* (Step 15)

IV. Evaluation Design, Phase 4

A. Who Will Do What? (Step 16)

1. Task Identification Matrix (Step 16)
2. Communication Structure and Tools (Step 16)

B. Evaluation Plans (Step 17)

1. Evaluation Plans for M & A Components (Step 17)
2. Evaluation Plans for M & A Implementation (Step 17)
3. Evaluation of inter/intra M & A Activities (Step 17)

C. Documentation and Communication (Step 18)

1. M & A Plan (**this document**, updated Sub documents) (Step 18)
2. Communication and Peer Review Plan (Step 18)
3. Action Plan* (Step 17)

**Italics mean a sub plan that might be attached or live somewhere else, location of document and contact is what would go in the plan*

For Sheet 9.8.a **Place your identified gaps and needs regarding this step in the *Action Plan* (what you need to plan to complete this step and or overall monitoring and assessment plan).**

Worksheet 9.8.a **Final *Action Plan* Part 1, Summary:**

If you have completed each Step, or for those you have, you have a cumulated list of gaps and needs related to that Step. Use that same worksheet/document. If you did not complete each Step, look at what each Step is supposed to accomplish and record what your gaps and needs are related to that topic. The goals are to get the gaps and needs in one place to evaluate and prioritize.

Phase 1 Step 1: (completed in Step 1)
Phase 1 Step 2: (completed in Step 2)
Phase 1 Step 3: (completed in Step 3)
Phase 1 Step 4: (completed in Step 4)
Phase 1 Step 5: (completed in Step 5)
Phase 1 Step 6: (completed in Step 6)
Phase 2 Step 7: (completed in Step 7)
Phase 2 Step 8: (completed in Step 8)
Phase 2 Step 9:
Phase 3 and 4 Steps: Will add Action and Needs as complete each Step and at the end prioritize

Background and Content

Variability and Site Selection

1. **Natural variability**: Sites that represent the "least altered" conditions in the watershed are known as reference sites. Having a good set of reference sites that reflect the natural condition of different types of waters throughout the watershed is a great way to get a handle on natural variability upstream to downstream. By monitoring these sites, you can actually find out what the natural variability is, because you actually measure it. For example, high elevation headwater streams are typically colder and have more shading than streams at lower elevations. If you find a measurable difference in dissolved oxygen levels when comparing a high and low elevation stream, it's likely a result of the natural variability from upstream to downstream. Many lakes "stratify" during the summer, where the upper water layers warm up and don't mix with colder layers below. So where in the water column you take your measurements can affect your results dramatically.
2. **Human-caused variability**: Site selection to isolate this type of variability usually involves "bracketing" a pollution source: one site directly upstream of the source, and two sites downstream. Differences in conditions between the upstream and downstream sites are a sign that pollution from this source is likely the cause of the change. When possible, choose sites with relatively uniform conditions (e.g., thorough mixing of the water, equal exposure to sunlight).
3. **Sampling and analysis variability**: Site selection is not the most important way to isolate errors in gathering field and lab data. However, some sites may be more difficult to sample than others and sampling errors may be more likely. Other sites may have complex flow patterns that make it difficult to sample. Deciding where at that site to collect a representative sample is a challenge, since conditions may vary across the channel. This makes it more likely that you will collect samples that are not representative of the entire site.

Generally, if you are doing a comparison among sites, their characteristics should be as similar as possible (e.g., geology, flow, size) in every way but the indicator you are measuring. This helps you to isolate the cause of any differences in results.

Selecting Sites - Basic Approaches

Two general approaches to picking sites reflect the scope of the assessment discussed earlier. If a broad assessment of the probable status of your water bodies in a large area is your goal, then the comprehensive scope is likely your best choice. If your focus is on finding and restoring impaired waters, then the targeted approach is probably best.

Comprehensive Assessment

Sites are either chosen to represent as many of the conditions in the watershed as possible or located randomly. For example, A "Cultural Ecosystem Story" may define sites throughout the watershed that support healthy fish populations-possibly at different times of the year. If so, start there! You could also randomly locate your sites using a probabilistic design. This design is used to assess conditions at the landscape or watershed scale, and the number of sites is chosen using statistical methods. Sites are placed into relatively homogenous groups, based on their geology, chemistry, aquatic life, etc. A relatively small number of sites are chosen that represent each group. Then they are placed in one of two types:

- Reference Sites are locations that reflect minimal change from natural or un-impacted conditions. These sites are used as benchmarks against which the conditions of the assessment sites are compared. In a comprehensive approach, reference sites are selected for each water body type. Ideally, you determine the condition of your assessment sites by comparing the results to those at the reference sites and determining the degree of change (usually a percent similarity; e.g., the assessment site is X% like the reference site).
- Assessment Sites are locations used to assess the degree of change resulting from the impact or process in which you are interested. Conditions at these sites are compared with those at reference sites or with water quality standards.

The comprehensive assessment will provide an overall sense of the watershed's health, but the information is not typically detailed enough to assess specific problems at specific locations. Examples of the comprehensive scope design include some state water quality assessments18, the USGS National Water Quality Assessment (NAWQA), and EPA's Environmental Monitoring and Assessment Protocol (EMAP).

Targeted Assessment

Sites are chosen to assess a particular problem source, source such as a discharge pipe, disturbed land area, eroding bank, etc. These problem sources may be suspected, presently known or upcoming. Problem sources may be at specific locations, but sometimes involve an area of disturbed land, such as an extensive construction site or paved urban area. The targeted approach usually focuses on assessing conditions at the reach scale, and provides information that can be used to identify or confirm problems, develop site-specific solutions or restoration strategies, and assess their performance. Because of this location-specific focus, the results do not really represent the current status of all waters.

In targeted assessments, sites are chosen to “bracket” a specific known or suspected pollution source:

- **Control Sites** are locations that represent the condition of the indicators being measured before they enter the problem area. These are sites that reflect minimal change from natural conditions. These sites are used as benchmarks against which the conditions at impact and recovery sites (see column to the right) are compared.

  In a targeted design control, sites are usually located just upstream of the problem area to be assessed. However, sometimes it's not possible to locate a good control site upstream of the problem area. In that case, the control site may be located on another reach that is similar in all respects to the reach being assessed. In either case, you determine the condition of your assessment sites by comparing the results to those at the control sites and determining the degree of change (usually a percent similarity; e.g., the assessment site is X% like the reference site).

- **Assessment Sites** are locations used to assess the degree of change resulting from the impact or process in which you are interested. Conditions at these sites are compared with those at control sites. Or, if you can't find workable control sites, use the water quality standards.

  Two common types of assessment sites are:

  Impact Sites: These are sites where the conditions have been altered by impacts such as point or non-point sources of pollution or a particular tributary. You compare the values from these sites to the control sites in order to assess the effect of the impact. Impact sites are typically located either immediately downstream or just outside of the source of the problem where the impact is thoroughly mixed into the water.

  Recovery Sites: These sites are located further away or downstream, where it is assumed that water quality has begun to recover from the impact(s). The values from these sites are compared to the impact sites in order to assess whether the water quality has improved, and also compared to the reference sites in order to assess whether the water quality is anything like it was before the impact.

General Site Selection Criteria

	COMPREHENSIVE ASSESSMENT Reference and Assessment Sites	**TARGETED ASSESSMENT Control, Impact, and Recovery Sites**
Water Body Type	Representative sites on all water body types in the watershed: Lakes, rivers, wetlands and groundwater	Sites focused on problem areas in the water of concern: Lakes, rivers, wetlands or groundwater
Human Uses	Representative of all human uses: ceremonial, drinking, bathing, swimming, travel, fishing	Sites focused on problem areas that affect the use(s) of concern
Aquatic Life Uses	Representative of all aquatic life uses: fish, invertebrates, algae, aquatic vegetation	Sites focused on problem areas that affect the aquatic animals or plants of concern
Physical Habitat	Representative of all habitat types: lakes, ponds, wetlands, streams/rivers (riffles/runs/pools), cold and/or warm water processes that create and maintain them: geomorphic classes, hydrology, substrate types (rocky to muddy), riparian vegetation	Sites on reaches with pollution sources that affect habitat
Water Column	Representative of different water column types: deep/slow, deep/fast, shallow/fast, shallow/slow	Sites focused on a problem area with the same water column type

A More Detailed Look at Types of Monitoring Sites

First, we will describe the different types of monitoring sites. Note that appropriate types of sites for each assessment are listed in the "Site Location Considerations" section of the surveys in the chapters that follow. Then we will describe some site-specific sampling location considerations – where to collect samples, measurements or observations at the site. Next, we will describe some practical considerations that you need to consider when selecting sites. Finally, we will cover the basic options for locations to analyze samples. In this section, we will discuss four different categories of monitoring sites:

General Watershed Assessment

- **Watershed Reference Sites**: Sites located in the least-developed parts of the watershed that represent "least-impaired" conditions.

- **Stream Impact Assessment Sites**: These sites include upstream reference, impact and recovery sites that bracket some sort of human alteration of the river system. See Section 2 below for a description of each. Locate these three sites wherever you wish to assess impacts in the watershed.

- **Fish Habitat Area Sites**: There may be various types of habitat areas, including areas designated as "cold water" and "warm water" habitats, and others which may be used by fish as spawning, nursery or resting areas.

- **Benthic Macroinvertebrate Macro-Habitats**: Riverine sites that include riffles, runs and pools:

  Riffle Sites: Shallow (1-2′ deep), fast moving (0.4 - 2.5 feet per second), cobble bottom areas.
  Run Sites: Deeper (>2′ deep), moderately fast moving (0.4 - 2.0 feet per second), sand and gravel bottom areas.
  Pool Sites: Deep (>2′ deep), slow-moving (<0.4 feet per second), mud-bottom areas.

  Within these larger macro-habitat areas and at each site, there will also be microhabitats that include different types of habitat structures: cobble bottoms, large woody debris, aquatic vegetation and submerged bank vegetation.

- **Water Use Sites**: These are sites where various types of human water use occur, such as swimming areas (formal and informal), boat launch areas, fishing access areas and water supply intakes.

- **Tributary Impact Assessment Sites**: These sites assume that the tributary may be considered a pollution discharge to the main stem of the stream (see figure 1 below). The idea is to bracket the mouth of each tributary assessed with four sites:

  Tributary Reference Sites: These sites are in the main stem of the stream, upstream of the confluence with the tributary. They represent conditions in the main stem prior to the impact of the tributary.
  Tributary Impact Sites: These sites are in the main stem of the stream, downstream of the confluence with the tributary, where the water from the tributary is completely mixed with the main stem1. Impact sites represent conditions in the main stem after the impact of the tributary.

[1] This is not easy to determine. It depends on the current velocity, the distance from the tributary outlet to the farthest bank, the depth of flow and the hydraulic forces across the stream. You may need to actually sample across the stream at various distances downstream of the tributary to determine where complete mixing occurs.

Tributary Recovery Sites: These sites are in the main stem of the stream, downstream of the impact site. They represent conditions in the main stem after the impacts of the tributary have begun to diminish.
Tributary Integrator Sites: These sites are at the mouth of the tributary. They represent the condition of the tributary, integrating all the upstream impacts, before it enters the main stem.

- **Lake Assessment Sites**: The main differences between monitoring lakes and monitoring streams are that the water flow through lakes is much slower, and lakes tend to be deeper. Frequently, in summer and winter, lakes stratify into layers of similar temperature that don't mix until spring and fall. So, in order to know what is going on in a lake, you need to look vertically in the water column as well as in different parts of the lake. Following are some different types of lake assessment sites that account for the horizontal and vertical variations:

Deepest Sites: The water in the deepest places in the main lake and in embayments tends to be the most representative of critical conditions in the lake. At these sites, you need to decide at what depth(s) you will take samples in order to assess the condition of different layers.
Mouths of Tributaries (Inlets): These are the same as the "tributary integrator sites" described above. They represent the condition of the tributary before it enters the lake.
Lake Outlet: These sites are located where the lake spills over a dam or enters a stream. They represent the conditions of the water as it leaves the lake.
Water Use Sites: These are sites where various types of human water use occur, such as swimming areas (formal and informal), boat launch areas, fishing access areas and water supply intakes. The idea is to assess conditions that affect these uses at these sites.
Near Shore Areas: Sites near the lakeshore are frequently the most heavily used and biologically productive areas of the lake. Many of the water use sites are located here as are many of the places most suitable for nuisance aquatic weed growth.

General Impact Assessment Sites

These include at least three sites that bracket some sort of human alteration of the stream system. These sites would be relevant to the Impact Survey Chapter.

- **Upstream Reference (Control) Sites**: These sites are upstream of some sort of human alteration of the stream. They represent conditions in the stream prior to the impact of the alteration.

- **Impact Sites**: These sites are downstream of some sort of human alteration of the stream. They represent conditions in the stream after the impact of the alteration.

- **Recovery Sites**: These sites are downstream of some sort of human alteration of the stream. They represent conditions in the stream after the impacts of the alteration have begun to diminish.

Public Health Monitoring Sites

The focuses for these sites are areas where people are coming into contact with the water or aquatic life. Examples include:

- swimming areas (formal and informal);
- boat launch areas; and
- fishing access areas.

The idea is to collect samples of water at these recreation sites to assess whether they are contaminated.

Habitat Assessment Locations

Habitat assessments can be carried out anywhere in the watershed, depending on the habitat of the organisms you are assessing. For the most part, habitat assessments focus on the channel and/or the riparian area:

- **Channels:** The channel carries the water during various magnitudes of flow in streams and lakes. It provides the physical structure and foundation for life in the stream or lake.

- **Shorelines and Riparian Areas:** As you move upland from the channel itself, there is a gradation to shorelines, riparian areas and the watershed itself. This is the land that drains into the stream or lake, from the top of the banks, to the floodplain, to upland areas.

Recommended Sites for The Four Assessments

As you think about recommendations for each kind of assessment, make note of your possible Data Quality Objectives (Step 10). Specifically, in Step 9, consider the following:

Representativeness: How many samples will you collect and where will you collect them to ensure that they represent the actual environmental condition or population you are sampling? This is important because, in most cases, you are only sampling a very small part of the watershed.

- the appropriateness of your sampling site selection for describing the general characteristics of the water body and specific impacts.
- the appropriateness of the location of the sample collection point: spatial location (mid-stream, mid-lake, etc.), sampling depth, number of sites, etc.

Following is a list of the types of sites we recommend for the 4 types of assessment covered in this workbook.

Condition and Trend Assessment

Water, habitat, and benthic macroinvertebrate sampling should be carried out at a variety of sites that represent a variety of conditions in the watershed. Select as many of the following types of sites as you can:

- sites on streams of different orders (sizes) and at different altitudes.
- watershed reference sites.

- stream impact assessment sites:
    - upstream reference (control) sites
    - impact sites
    - recovery sites
- benthic macroinvertebrate riffle habitats.
- tributary impact assessment sites:
    - reference sites
    - impact sites
    - recovery sites
    - integrator sites
- cold and warm water fish habitat areas (spawning, nursery, and resting sites).
- where possible, sites historically monitored by the DEP.
- stream channel reference sites that are stable and represent different stream types.

Point and Non Point Source Impact Assessments

Water, habitat, and benthic macroinvertebrate sampling should bracket specific pollution sources or groups of pollution sources (see Chapter 2, Step 6 for definitions of types of sites):

- watershed reference sites.
- stream impact assessment sites that bracket the source:
    - upstream reference (control) sites
    - impact sites
    - recovery sites
- where possible, sites historically monitored.
- benthic macroinvertebrate sampling from riffle habitats.
- sites which are representative of the reach of the stream of interest.
- sites which are safely accessible.
- sites where the main stream current is accessible -- where the water is thoroughly mixed.

Use Support Assessment

Water, habitat, and benthic macroinvertebrate sampling should be carried out at a variety of sites that represent a variety of conditions in the watershed. If you have done an Impairment Screening/Biological Assessment (B1), you may have pinpointed one or more particular problem reaches. Then you may only need to sample a few sites on that reach. However, you will need to establish some sort of reference site, if you plan to carry out benthic macroinvertebrate monitoring. If a good one is not present in your reach, you may need to sample one elsewhere in the watershed.

Select as many of the following types of sites as you can:

Watershed Sites:

- sites on streams of different orders (sizes) and at different altitudes.
- watershed reference sites.
- stream impact assessment sites:

upstream reference (control) sites
impact sites
recovery sites

- benthic macroinvertebrate riffle habitats.
- tributary impact assessment sites:
  reference sites
  impact sites
  recovery sites
  integrator sites
- cold and warm water fish habitat areas (spawning, nursery, and resting sites).
- where possible, sites historically monitored.
- benthic macroinvertebrate sampling from riffle habitats.
- boat launch ramps and fishing access areas.
- cold and warm water fish habitat areas (spawning, nursery, and resting sites).

Reach Sites:

- sites which are representative of the reach of the stream of interest.
- sites which are safely accessible.
- sites where the main stream current is accessible -- where the water is thoroughly mixed.

Water Contact Recreation Sites

- Designated beaches and areas designated for swimming, wading, diving, and water skiing.
- Informal swimming, wading, diving, and water skiing areas.
- Boat launch ramps and fishing access areas.
- Below pollution sources.
- Where possible, sites historically monitored .

Practical Considerations for Site Selection

- **Accessibility and Safety** - Avoid steep, slippery or eroding banks or sites where landowner permission cannot be obtained.
- **Distance between sites** - Make sure any difference in values between sites is NOT a result of natural variation in time of day. For example, because dissolved oxygen levels can naturally increase in a short period of time in the morning, measurements or samples at all of your sites should be taken within a fairly narrow window of time. You will also have to consider distance between sites when you are taking samples that have short holding times. For a period of time, financial and staff resources may also limit the number of sites and how far apart they can be.
- **Previously collected information** - Where possible, it helps to choose sites that have been previously assessed in order to build on that information.

Case Study 1

Case Study 2

References

Barbour, Michael et al, 1999, Rapid Bioassessment Protocols for Use in Wadeable Streams and Rivers: Periphyton, Benthic Macroinvertebrates and Fish. Report # EPA841-B-99-002, U.S. EPA, Washington D.C., May 1989.

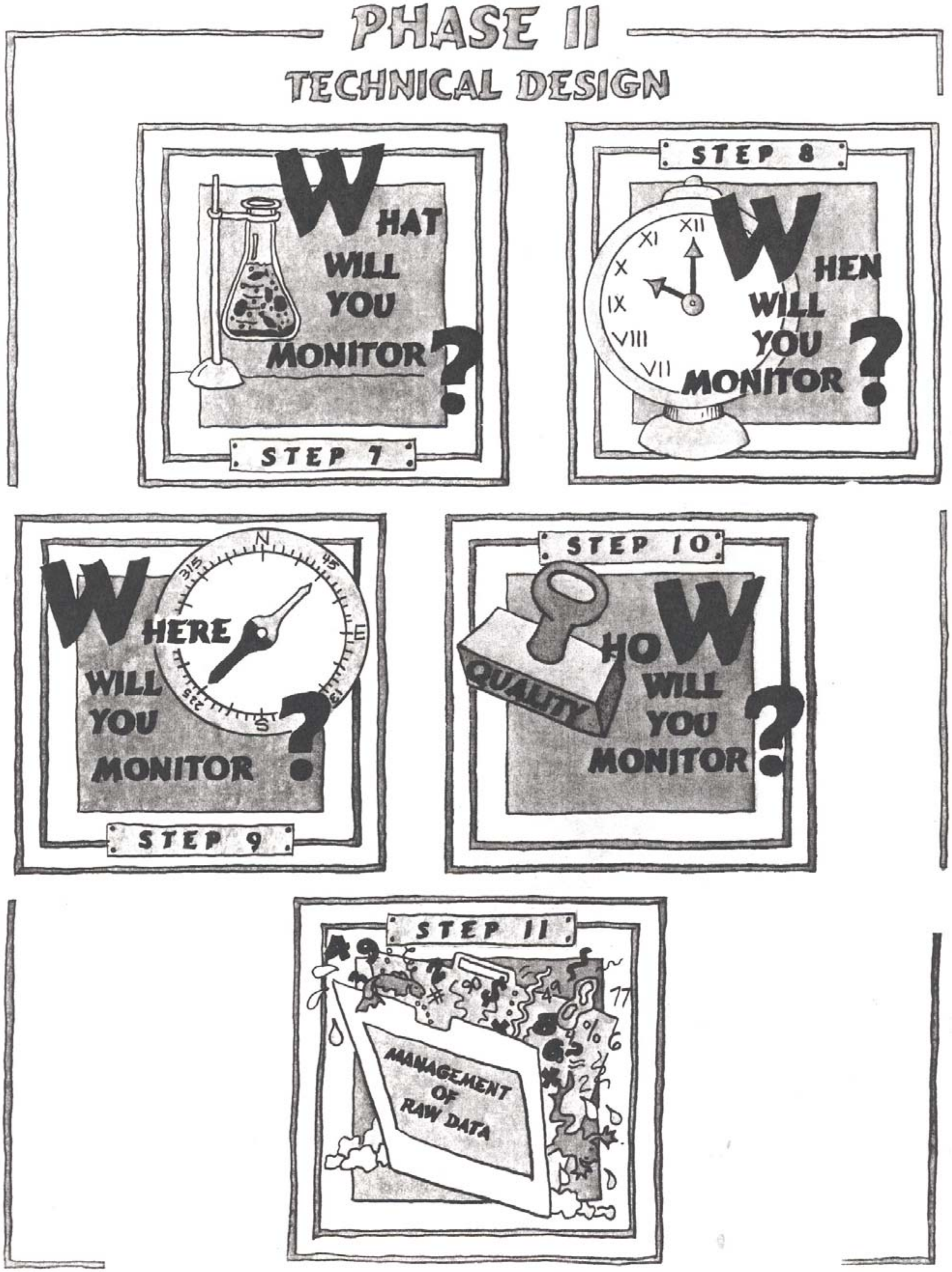
Federal Interagency Stream Restoration Working Group (FISRWG), 1998. Stream Corridor Restoration: Principles, Processes, and Practices. National Technical Information Service (NTIS) , Springfield, VA. (Available online: http://www.usda.gov/stream_restoration/newgra.html)

Harrelson, Cheryl C., 1994. Stream Channel Reference Sites: An Illustrated Guide To Field Technique, U.S. Forest Service General Technical Report RM-245, Fort Collins, CO.

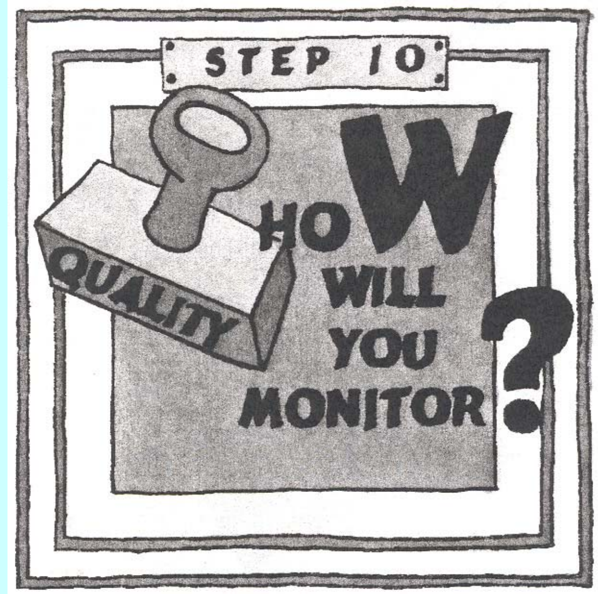
U.S. EPA, 1997. Guidelines for Preparation of the Comprehensive State Water Quality Assessments (305(b) Reports) and Electronic Updates: Assessment and Watershed Protection Division (4503F) Office of Wetlands, Oceans, and Watersheds, Washington, D.C. 20460.

U.S.EPA, Selecting a sample design, where/when factors for analyses, quick check list, http://www.epa.gov/quality/qksampl.html

Resources


PHASE II
TECHNICAL DESIGN
WHAT WILL YOU MONITOR?
STEP 7
STEP 8
WHEN WILL YOU MONITOR?
WHERE WILL YOU MONITOR?
STEP 9
STEP 10
HOW WILL YOU MONITOR?
QUALITY
STEP 11
MANAGEMENT OF RAW DATA

Step 10: How Will You Monitor to meet Data Quality Objectives



"What is a deadline but a row of gravestones with rest in "PEACE" etched into each cold hard face? I would not tear myself from the throes of passion for a date with a dead line—would you? No one can kiss you when you stand on the other side of the dead line, do the dance of life."

Jane Evershed

About This Step – *This step is designed to accomplish 3 things:*

1. **Set data quality objectives** (How complete, representative, comparable, accurate and precise does the data you gather need to be in order to be useful?).
2. **Select sampling and analysis methods** that meet your data quality objectives and match your capabilities.
3. **Describe your quality control system** and how it will assure that you meet your data quality objectives.

Why Do This Step

Now that you've decided what indicators to measure, and where and when to measure them, the next step is to decide how to measure them. In previous chapters, we discussed the types of variability in watershed assessments (natural, human activities and experimental) and the need to determine how each affects your results. Measuring the variability due to natural and human activities is hard enough! You don't want to confuse the issue by introducing experimental variability: that which results from your data gathering methods. Unfortunately, you can introduce additional sources of variability at every step in sampling and analysis. Your goal is to be able to assume that any difference in watershed condition you see in your assessment is a result of the actual difference in the indicator (in time and/or space), rather than from differences you caused in sampling and/or analysis.

Fortunately, you actually have some control over experimental variability by setting your own data quality objectives, choosing the right collection and analytical methods, and putting a quality assurance program in place to let you know whether you're meeting your objectives.

In Step 5, you chose data quality objectives (DQOs) to meet the needs of your data users. In this step, you select analytical methods that will meet those objectives. In the process, you may find that the methods that meet your DQOs are too difficult, time consuming, or expensive. You may find that the method(s) you've been using are not precise or sensitive enough to meet your decision-makers' needs.

In this step, you select methods that meet your DQOs AND are within your capabilities. It's critical that you find this out before you finalize your plan.

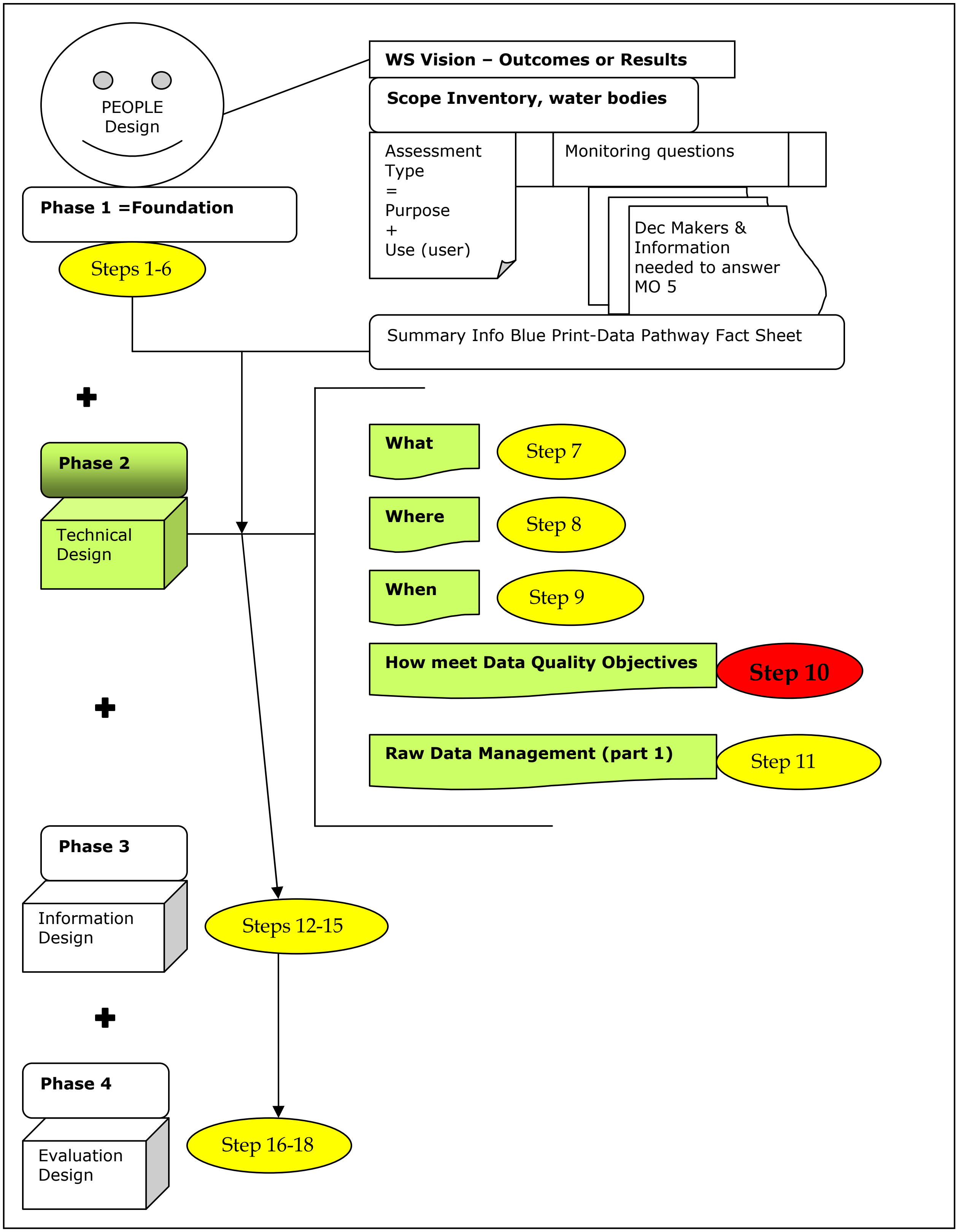
Where are we in the Big Picture Illustration?

Phase 1	Step 1: Share Watershed Vision and Desired Outcomes (Results) Step 2: Scope Inventory (Physical, People and Information) Step 3: Identify Monitoring Reason(s) and Data Use(s) (Assessment Type) Step 4: Develop Monitoring Questions (Refinement of Monitoring Reason) Step 5: Target Decision Makers and Info Needs (Refinement of Data Use) Step 6: Summarize with Information Blue Print-Data Pathway Fact Sheet)
Phase 2	Step 7: What Will You Monitor? Step 8: When Will You Monitor? Step 9: Where Will You Monitor? **Step 10: How Will You Monitor to Meet Data Quality Objectives?** Step 11: Management of Raw Data (Data Management Plan Part 1)
Phase 3	Step 12: Data Summary and Analysis Step 13: Interpretation, Conclusions and Recommendations Step 14: Communicating and Delivery Step 15: Management to Generate Info (Data Management Plan Part 2)
Phase 4	Step 16: Who Will Do What? Task Identification Step 17: Evaluation of Effectiveness (of Plan and Implementation) Step 18: Documentation and Communication (of M & A Plan)

Products

- ✓ A summary of data quality objectives for sampling and analysis that meet the information needs of all decision makers per monitoring question per Assessment Type.
- ✓ A list / documentation of sampling collection and analysis methods.
- ✓ A quality control plan.

Phase 2 Product Illustration:



What Should Be Done Before This Step?

A list of indicators (Step 7) for each monitoring question per Assessment Type, a characterization of monitoring frequency for each indicator (Step 8) and sample sites and where within each site a sample will be collected (Step 9).

The information listed in the Final Information Blue Print-Data Pathway Fact Sheet, Worksheet 6.3.a in Step 6. This information needs to be provided for every monitoring question per each Assessment Type. The summary sheet should be completed as much as possible but is a starting point. Worksheet 5.4.a and 5.4.a lists the information needed by targeted decision makers and associated data quality objectives. You may also have found valuable information from the Scoping Inventory, especially Worksheet 2.9.a, Worksheet 2.11.a, Worksheet 2.12.a and Worksheet 2.13.a.

- Worksheet 6.3.a is the summary Information Blue Print – Data Pathway Fact Sheet for each monitoring question per Assessment Type, selection of Assessment Type was Worksheet 3.4.a.
- Worksheet 5.4.a and 5.4.b, information needed by targeted decision makers and associated data quality objectives
- Worksheet 2.9.a, Physical Attributes of target water bodies
- Worksheet 2.11.a, Impact Features of target water bodies.
- Worksheet 2.12.a Water body stressor Identification.
- Worksheet 2.13.a Water body Status and/or condition

The assessment type narrows down the parameters you need to consider. Further, tables later in this chapter will help you narrow the field even further.

Steps 1 through 6, Phase 1, do not need to be completed per say, but the information that is a result of those steps are necessary to identify and define to design the monitoring components of what, when, where and how you will gather data. This information is also necessary to plan how the data will generate information, be managed, analyzed, interpreted, delivered to decision makers and evaluated. Information generated in Steps 1-6, Phase 2 are the foundation of every monitoring program.

Thus, ideally you need to have identified a watershed vision and desired outcomes with associated assumptions and external factors. Defined combination of monitoring reasons and uses, we call Assessment types. For each assessment type a list of monitoring questions the data is to answer and how that question will be answered. For each monitoring question, a list of targeted decision makers, their decision, how they make that decision and what information they need to make the decision. Once you have this, you can summarize the results in any format, we suggests the information blueprint we suggests the information blueprint – data pathway fact sheet from Step 6, Worksheet 6.3.a.

Basic Tasks

Basic Tasks are numbered to correlate with the overall 1-18 Steps provided in these guidance modules followed by the basic task sequence step to complete. For example Step 4, basic task 2 would be numbered as Basic Task Step 4.2, Step 3.3 correlates to Step 3, Basic Task 3.

10.1	Identify who will make the decisions about this step and who should be involved in the planning process (they may be different).
10.2	Self Assessment: If you've been monitoring before you've undertaken this process, have the parameters you've measured worked well?
10.3	Sampling Methods and Data Quality Objectives
10.4	Analytical Methods and Data Quality Objectives
10.5	Update *Inventory Master List* and *Plan.*
10.6	Update *Information Blueprint – Data Pathway Fact Sheet* for each monitoring question.
10.7	Place Products in your *Watershed Monitoring and Assessment Plan*.
10.8	Place your identified gaps and needs regarding this step in the *Action Plan* (what you need to plan to complete this step and or overall monitoring and assessment plan).

Worksheets

Work sheets are listed below. Not all Basic Tasks have an associated work sheet. To simplify completion of products for each step, the worksheets or broken into small subsets of tasks. This requires moving the results of one task into the next task and will seem redundant, especially if completing worksheets by hand. Worksheets are provided in word here for ease of reproducibility. These are a starting point; we encourage you to customize these and reproduced them in an electronic format, in Excel for example, where it is easy to move information from one area to another by cutting and pasting.

Work Sheets are numbered to correlate with Basic Steps and the overall Steps in these guidance modules. Each consecutive work sheet is lettered a, b, c and so forth, preceded by the Basic Task sequence step, preceded by the Step number. For example, Worksheet Step 4.2.a and Step 4.2.b, correlates to Step 4, Basic Task 2, Worksheet a and Worksheet b. In theory worksheet a needs to be completed before worksheet b.

Worksheet 10.2.a **Self Assessment Step 9 Worksheet and Products to be completed Prior to this Step, Part 1 and Part 2.** If you've been monitoring prior to using this planning process, you've got some experience with some of the parameters. In this worksheet, you will evaluate the use and effectiveness of your current parameters.

Worksheet 10.3.a **Select Sampling Data Quality Objectives**

10.3.b **Select Sampling Methods**

Worksheet 10.4.a **Select Analytical Data Quality Objectives**

10.4.b **Select Sample Analysis Methods**

Worksheet 10.5a **Quality Control Measures**

Worksheet 10.7.a **Place Products in your** *Watershed Monitoring and Assessment Plan.*

Worksheet 10.8.a **Place your identified gaps and needs regarding this step in the** *Action Plan* **(what you need to plan to complete this step and or overall monitoring and assessment plan).**

How To Do Worksheets

For Sheet 10.2.a Self Assessment Step 10 Worksheet and Products to be completed Prior to this Step. Part 1.

Part 1. Complete the self assessment section of the worksheet to evaluate what you have or what decisions have already been made. This will help you focus on what you need from this step and incorporate valuable existing information or products into this plan.

Part 2. Next, to prepare to complete this step the following, you need to have the following items addressed:

- ✓ Desired set of outcomes or results that the monitoring and assessment activities will be designed to help achieve
- ✓ Identified monitoring and assessment activities, specific combinations of a monitoring reason plus an associated data use; we call this an Assessment Type. You may have multiple Assessment Types.
- ✓ For each Assessment Type, the list of specific monitoring questions the monitoring and assessment will be designed to answer.
- ✓ For each monitoring question, the targeted decision makers, the type of decisions they will make and the information they need to make them (as specific as possible).
- ✓ A minimal scoping inventory that identifies the watershed boundary and water bodies you are focusing on (rivers, lakes or wetlands), physical attributes of water bodies (including status, uses, etc.), relevant cultural or historical aspects, existing data sets or monitoring efforts and others in the watershed who either you want to influence or could help you implement.
- ✓ Technical sample plan including what monitor (indicators, benchmarks, criteria, etc.), where and when monitor, how will meet data quality objectives (methods, how good does the data need to be for decision makers, quality assurance and control measures), and how will manage and verify raw data/information- AT THIS POINT WHAT YOU KNOW, if you don't know it, Phase 2 and 3 help you determine these items.
- ✓ Set of indicators from Step 7 and frequency characterization from Step 8, station locations from Step 9

This is the ideal list, if you do not have any of these, they become a gap or need that should be addressed before any data is collected or analyzed, even if the answers aren't perfect or you don't have a large degree of confidence surrounding them, they should be attempted as the starting point. This is what you are evaluating in this step-your monitoring and assessment plan.

Worksheet 10.2.a Self Assessment Step 10 Worksheet and Products to be completed Prior to this Step. Part 2.

Part 1 Self Assessment of Known Evaluation Products and Processes

1. **Determine if you "have" or "don't have" the item, mark the appropriate box. If you don't have it and determine you don't need it, explain why in the comments document. You may not need to know but perhaps your target decision makers, board or membership might want to know.**

2. **If you have the item "documented", mark that box. If so, list in the comments where, hard copy, chapter in a document, electronic file name and location, etc. The assumption is you value the ultimate goal to document and communicate your M & A plan, activities and results.**

3. **If you have the item, assess the use of it, use the scale below or provide your own answer and comments.**

   Rating Scale for USE:
   - 0=doesn't exist so use is nil
   - 1=don't know why would need or understand item
   - 2=exists, don't know where it is, if it is used, etc. so use is essentially nil
   - 3=exists and use some of time
   - 4=exists and use all the time
   - 5=wish it existed, would use it lots

4. **If you have the item, assess the effectiveness of it, just because something exists or is used does not mean it is effective in its use, use the effectiveness scale below or provide your own answer and comments.**

   Rating Scale for EFFECTIVENESS, assumes material exists:
   - 0=not effective or functional at all
   - 1=incomplete (all elements are not there) and some existing parts need revising
   - 2=incomplete but what is there is okay
   - 3=complete (all elements are there), some parts okay but need revising
   - 4=complete and effective

Item	Have	Don't Have	DOC	Assessment of Use (Scale 0-5)	Assessment of value / effectiveness (Scale 0-4)	Comments/Notes
27. Written field/collection methods						
28. Written Laboratory Protocols						
29. Identified source of monitoring protocols (collection, field, lab, etc.)						
Other?						

*DOC=Documentation, *M & A= Monitoring and Assessment

5. To make this assessment useful, determine what your gaps and needs are regarding this step in order to focus your effort in completing this step.

Worksheet 10.2.a Self Assessment Step 10 Worksheet and Products to be completed Prior to this Step.

Part 2 Products to be completed before this step, in order to complete this step, what know from Step 5 and Step 6, Worksheet 6.3.a. Step 7 finalized indicators to this point. If you don't know, you will after this Step.

Item	Response
Desired set of outcomes or results that the monitoring and assessment activities will be designed to help achieve:	
Assessment Types, specific combination of one monitoring reason and data use(r):	
For each Assessment Type, the list of specific monitoring questions:	
For each monitoring question, the targeted decision makers, the type of decisions they will make and the information they need to make them (as specific as possible):	
Watershed(s) and Water bodies of focus:	
Physical attributes of Water bodies (status, use, etc.)	
Existing Data or monitoring efforts:	
Indicators, benchmarks and criteria list (STEP 7):	
For each indicator, when monitor? (STEP 8):	
List of monitoring locations/rationale (STEP 9):	
List of monitoring frequencies:	
Methods list, list of data quality objectives (methods, how good does the data need to be for decision makers), quality assurance and control measures)	
What you know now about decision makers data-to-information needs, analyses, interpretation and reporting	

For sheet 10.3.a Select Sampling Data Quality Objectives

List your objectives for completeness, representiveness, and comparability. Please refer to the background section above for detailed descriptions and information.

For sheet 10.3.b Select Sampling Methods

1. *What you are going to sample?* (e.g., the water column, the bottom of the lake, riparian habitat, etc.)
   - Rainfall might be measured by recording the water level in a gauge.
   - Abundance of waterfowl might be estimated with counts.
   - Human health might be assessed by taking blood or hair samples to analyze the amount of the contaminant that has been absorbed or deposited.
   - pH of the water column will be measured.
   - Trends in the smell of fish might be assessed by direct observation and narrative descriptions.
   - Stream flow or discharge might be measured by using information about the area of the channel and the velocity of the water.

General Terms Used In Sampling Grab Samples:

Samples are collected in some type of container by dipping the container in the water and filling it to some pre-determined level.

* **Integrated Depth Samples**: Samples are collected from various depths or locations across a transect that are combined into one sample for analysis.
* **Multiple Depth Samples**: Individual samples are collected at various depths and analyzed separately.
* **Artificial Substrate**: A sampler is placed in the water column or on the bottom and colonized by critters or plants.
* **Direct Measurement**: The indicator is measured directly from the water without collecting a sample.

Some other examples include:		
stream or lake water	sediment	zooplankton
groundwater	macrophytes	wastewater
benthic macroinvertebrates	algae	rain
discharge	maps	storm water
fish	periphyton	
habitat	phytoplankton	

2. *What you will use to collect samples?* (e.g., your eyes, a meter, sample container type, etc.)
   - Invertebrates might be collected with a kick net.
   - Bacteria might be collected in a Whirl-pak bag.
   - Fish might be collected by electro-shocking.
   - Water samples might be collected in a plastic bottle.

Sampling Containers or Devices		
plastic bottle	collection net	Surber sampler
BOD bottle	rock basket	meter secchi disk
glass bottle	Whirl-pak bag	integrated depth sample
Dredge	acid-rinsed glass	

3. *Whether and how you will preserve samples?* (e.g., freezing, acidification, immersing critters in alcohol or some other preservative)

- Invertebrates might be preserved with alcohol.
- Bacteria samples taken downstream of a wastewater treatment plant should be mixed with sodium thiosulfate in order to preserve colony numbers.
- Dissolved oxygen samples, being analyzed with the Hach Azide Modification of the Winkler titration method, will need to be "fixed" in the field using manganous sulfate, alkaline iodide-azide and sulfamic acid.

Preservation Methods		
Acidified Fixed	Alcohol formalin	Refrigerated dark

4. *Quantity of sample to be collected:* How much of the sample will be collected? This is determined by the needs of your analytical method.

Some examples include:	
milliliters # of organisms area sampled	cubic centimeters # of transects # of measurements

5. *Number of samples to be collected per site:* How many samples will be collected at each site? Examples to explain, "How many samples and how much?" could include: , 2 - 500 mL samples of the water column, 3 - 1 square-meter samples of the bottom of the lake, one observation of 300 feet of riparian habitat, etc.
   - You might collect 500 ml water samples at 3 different depths.
   - You might assess the habitat of one riffle in 10 different locations.
   - You might assess the smell of 5 different fish from one spot.
   - You might collect two secchi depth readings at each lake site.
   - You might need to collect at least 3 benthic macroinvertebrate samples from 1 square meter of river bottom.
   - You might count waterfowl at 10 locations to get a good average.

6. *Methods Reference:* Reference the source of your sampling method.

Worksheet 10.3.a Data Quality Objectives for Sampling

For each sample type, list the objectives.

Sample Type	Completeness	Representativeness	Comparability

Worksheet 10.3.b Sample Collection Methods

Indicator	What will be sampled	Sampling containers or devices/ preservation	Quantity of sample to be collected	Number of samples to be collected per site	Methods Reference

For Sheet 10.4.a Select Analytical Data Quality Objectives

List your objectives accuracy, precision, and detection limit/measurement range. Please refer to the background section above for detailed descriptions and information.

For Sheet 10.4.b Select Analytical Methods

EXAMPLES: Analysis Data Quality Objectives

* To produce results within 10% of known metal concentrations (accuracy)

* To produce results within 10% between multiple tissue samples (precision)

There is usually more than one way to collect the information you're after. Sample collection and analysis methods range from simple and inexpensive, to complex and cost-prohibitive. On one end of the spectrum, systematic observations or photographs may be all you need to document obvious pollution problems. At the other end, you may need to use difficult and expensive methods to find a very low concentration of a pollutant that is causing the problem. To add to the confusion, equipment manufacturers want to sell you equipment, and people who have used a certain method for a long time may be biased and recommend methods that won't meet your needs or capabilities.

1. *How you will transport the samples to the lab, and how long you can keep the samples before they must get there?* (e.g., in coolers within 6 hours)
    - Samples taken for bacteria analysis will need to be refrigerated so that the number of colonies does not change.
    - Dissolved oxygen samples will need to be kept in a dark container.
    - Samples taken for pH analysis typically need to be analyzed as soon as possible.

2. *What is the maximum time a sample can be kept before it must be analyzed?* The maximum amount of time that the sample can be held before it must be analyzed. Some holding times for common water column indicators are listed in the table below. Some indicators don't have a limit on the amount of time they can be held. For these, fill in "NA" for "not applicable." See table below. Examples include:
    - Bacteria samples must be analyzed within **8 hours** of collection.
    - Macroinvertebrate samples preserved in alcohol may be kept **indefinitely**.
    - Chlorophyll *a* must be analyzed within 30 days.Sample Handling Requirement

from Standard Methods				
Indicator	**Container Type**	**Minimum Size (mL)**	**Preservation**	**Max. Holding Time**
Alkalinity	P, G	200	Ref.	24 h
Bacteria	P, G (S)	200	Ref.	6 h
BOD	P, G	1000	Ref.	6 h
Chlorophyll	P, G	500	Dark	30 d
Conductivity	P, G	500	Ref.	28 d
N-Ammonia	P, G	500	ASAP or acidify	7 d
N-Nitrate	P, G	100	ASAP or ref.	48 h
N-Kjeldahl	P, G	500	Ref., acidify	7d
Oxygen	G-BOD	300	Fix	8 h
pH	P, G	-	ASAP	2h
Phosphate	G(A)	100	Ref.	48 h
Solids	P, G	-	Ref.	7 d
Turbidity	P, G	-	Ref., Dark	24 h
Abbreviations P = Plastic, G = Glass G(A) = acid-rinsed glass (S) = sterile		Ref. = refrigerate h = hours, d = days		

3. *Methods Reference: Cite a specific method and reference the source of your sampling method*. This will often be a numeric reference code typically in Standards Methods of EPA Methods. For example, "grab sample per Standard Methods 9500A."See the background section above for more information.
4. *Brief Description of Methods: Include a 1-2 sentence description of the method*. For example: "Membrane filtration and incubation for two hours at 35° C followed by 18 – 24 hours incubation at 44.5° C". You can find these in the background section above or in the methods column of the Assessment Tables.
5. *How will you report the results?* (e.g., as a concentration of mg/L, # of critters in each family, percentage of habitat in each vegetative type, etc.)
   - Bacteria results are typically reported as number of colonies per 100 milliliters (cfu/100ml).
   - Benthic macroinvertebrate results are usually expressed as the number of critters of each type (taxon).
   - Abundance of waterfowl might be reported as **number per square area**.
   - Medicinal plants, invasive species or dead fish might be reported as **present or absent**.

Common reporting units include:	
mg/l cfu per 100 mL cubic ft/sec	NTUs °C or °F meters or feet

Worksheet 10.4.a Data Quality Objectives for Analysis

For each indicator, list the objectives.

Indicator	Accuracy	Precision	Detection Limit/Measurement Range

Worksheet 10.4.b Sample Analysis Methods

Indicator	How Sample Transported to Lab	Maximum holding time	Method Reference	Brief Description of Method	Reporting Units

For Sheet 10.5.a Quality Control Measures

This worksheet lists the quality control measures you will follow to enable you to assess whether you've met your data quality objectives for sampling and analysis.

Quality control details the technical activities used to identify and control errors resulting from sampling and analysis procedures. There are two general types of quality control measures used to assess the precision and accuracy of your monitoring results:

- ✓ **Internal Quality Control Measures:** Internal quality control measures are samples collected and analyzed by project field volunteers, staff and laboratory. Most of the QC measures you choose will be internal, and the focus of your plan.
- ✓ **External Quality Control Measures:** External quality control measures are samples collected and analyzed by non-volunteers field staff and or certified laboratories that aren't normally part of your monitoring program.

Parameter(s)

List the parameters you will be monitoring and the quality control samples you will run on each. If a group of parameters will be measured out of each sample, you can list all the parameters in one cell, call it sample group 1, or anything you would like to call the group.

% Quality Control Samples

List the % of your total samples that will be quality control samples. The column headings in the worksheet are filled in (Field Blanks Field Duplicates, Lab Duplicates, Calibration Standards, and Spikes) but you can change any of those. As a general rule of thumb, 5-10% of your samples should be quality control samples. These recommendations are starting points only. You will need to work with your technical committee and especially your primary data user to make this decision.

Remember who you have identified as the primary data user and the expected data use. If data is strictly for educational purposes, extensive QC measures are probably not required. On the other hand if you are doing monitoring to assess water use for state standards, stricter QC measures are required. You'll probably be somewhere in between. Refer back to the Step 3 Exercise: Talking to Your Data User, to make note of any specific data user requirements.

Some examples of quality control measures include (see the background and Content section of this step for more detail):

Field Blanks: A field blank is de-ionized or distilled water that is poured into a sample container in the field as if it were a lake or stream sample.

Trip Blank: A trip blank is appropriate "blank" water placed in a sample container (with appropriate preservation) prior to going out to collect samples.

Sampler Blank (aka rinsate or equipment blank): a sampler blank is de-ionized or distilled water that is rinsed through the sampling device, collected and analyzed.

Method Blank: A method blank is de-ionized water or distilled water process like any of the other samples.

Calibration Blanks: A calibration blank is de-ionized or distilled water processed like any of the samples and used to "zero" the instrument.

Calibration Standards: Calibration standards are used to calibrate a meter.

Field Duplicates: A field duplicate is a duplicated stream or lake sample collected and analyzed.

Laboratory Duplicates: A laboratory duplicate is a sample that is split into two or more sub-samples at the laboratory.

Spike Samples: A sample is "spiked" by adding a known amount of a known concentration of the parameter being measured.

Negative and Positive Plates (for bacteria):

Negative plates: Buffered rinse water (the sterile water used to rinse down the sides of the filter funnel during filtration) is filtered in the same manner as a sample.

Positive plates: Water known to contain bacteria (such as wastewater treatment plant influent) is filtered the same way manner as a sample.

Evaluation of Results: the results for negative planes should be "zero." The results for positive plates should be "too numerous to count" (TNTC).

You may want to review additional choices of quality control measures. A complete description of internal and external quality control measures and how they are evaluated is found in the Background and Content section of this step. Recommended Quality Controls for Advanced and Basic Assessments can be found in Appendix 10.5.

% Quality Control Samples

The percentage of your samples that will be subject to a specific quality control measure is not set in stone. It will vary for a number of reasons, such as, the parameter sampled, the level of rigor you have chosen, your data user requirements, the goals of your project, etc. As a general rule of thumb, 5-10% of your samples should be quality control samples. These recommendations are starting points only. You will need to work with your technical committee and especially your primary data user to make this decision.

Evaluation

Evaluation involves calculating the accuracy and precision of your quality control measures and comparing them to your data quality objectives. In this column, list who and how you will evaluate the quality control samples in terms of whether you met your data quality goals.

The decision to accept or reject data or a portion of it is made after the analysis of all the QC data.

Problem Avoidance and Response Actions

Describe how you will avoid problems and, when they occur, respond to them. See the Background and Content section of this step for a fuller description and examples.

Example of Worksheet 10.5.a Quality Control Measures

Parameter	% Quality Control Samples					Evaluation
	Field Blanks	Field Dups.	Lab Dups.	Calib Stds.	Spikes	
Total Phosphorus	10% of all sites	10% of all sites	10%	Each run	1/run	Performed by certified lab
Secchi Disk	NA	Each sample	NA	NA	NA	Performed by trained volunteers in field (see precision goals in worksheet 5.4) RPD
T-Tube	NA	Each sample	NA	NA	NA	Performed by trained volunteers in field (see precision goals in worksheet 5.4)
Dissolved Oxygen (by meter)	NA	10%of all samples	NA	Each sampling day – using an oxygen saturated sample	NA	Performed in field with trained volunteers and read as the expected concentration within defined limits. Help is gotten if accuracy & precision isn't reached (see worksheet 5.4)

NA = Not applicable to this parameter

Response Action: If a response action is needed, we will define the problem and troubleshooting to determine the problem source. Once identified the problem will be resolved according to established guidelines.

Worksheet 10.5.a: Quality Control Measures

Parameters	% Quality Control Samples							Evaluation
	Field Blanks	Field Dups.						

Response Action: If a response action is needed, we will define the problem and troubleshooting to determine the problem source. Once identified the problem will be resolved according to established guidelines

For Sheet 10.6.a Instrument and Equipment Requirements

Your results are only as good as your sampling and analytical equipment. Therefore, it is important to routinely maintain, inspect and calibrate it. It is also important to document these activities and keep records in a logbook or on data sheets. This will help in troubleshooting should problems arise with your quality control samples. It is also important to know when the equipment was purchased and where it was purchased. It may be necessary to contact the manufacturer for information. They will also need to know the model and serial number. It is good to have it documented in your plan, as this information is easily lost.

In this worksheet you will outline your plan for the routine inspection, calibration and preventative maintenance of field and laboratory equipment. This includes how frequently, types of standards or certified equipment that will be used for calibration and documentation. The following is the type of information you will need.

- Equipment Type: Include the specific name of the equipment, model number, serial number and what the equipment is used for.
- Documentation: Include when purchased, where purchased, and if there are instructions.
- Inspection, Calibration and Maintenance

Example 1 of Worksheet 10.6.a Instrument and Equipment Requirements

1. **Equipment Type and Parameter:** Portable field YSI 60 pH meter, # 01- 56972
2. **Documentation:** Purchased January 2002, from YSI; will follow instruction manual
3. **Inspection, Calibration, and Maintenance:** Prior to each sampling event: Check electrolyte level in electrode, and fill with KCl as necessary. Results kept in logbook. Use manufacture's instructions for calibrations.

Example 2 of Worksheet 10.6.a Instrument and Equipment Requirements

1. **Equipment Type and Parameter:** Integrated Sampler for total phosphorus and chlorophyll 'a'
2. **Documentation:** Purchased May 2001 from XYZ Laboratories, manufacturer's instructions
3. **Calibration**: is not required

   Inspection: Check to make sure stored and cleaned as directed below.

   Maintenance:

   a. Clean at the beginning of each sampling season
      - In a clean container dissolve 1/2 box of baking powder in 1 gallon of water
      - Plug one end and fill half way with cleaning solution
      - Plug other end and rotate and tilt sampler to clean all surfaces, making sure not to sampler ends
      - Discard cleaning solution and repeat until all the cleaning solution is used

- Rinse thoroughly 3 times with tap water

b. Storage when not in use

- Store DRY and corked on both ends
- Store away from kids, pets and other animals such as mice
- For added protection, cover each end with a new plastic bag and fasten them

Worksheet 10.6.a Instrument and Equipment Requirements

1) Equipment Type:

2) Documentation:

3) Inspection, Calibration, and Maintenance:

---

1) Equipment Type:

2) Documentation:

3) Inspection, Calibration, and Maintenance:

---

1) Equipment Type:

2) Documentation:

3) Inspection, Calibration, and Maintenance:

---

1) Equipment Type:

2) Documentation:

3) Inspection, Calibration, and Maintenance:

For Sheet 10.7.a **Place Products in your** Watershed Monitoring and Assessment Plan.

- Documentation of methods and procedures in field and laboratory and all other processes, identification and documentation of data quality objectives necessary to meet information needs of target decision makers, monitoring questions, Assessment Type desired outcomes and a quality control plan

Worksheet 10.7.a **Add products of Step to** *Watershed Monitoring and Assessment Plan.*

If you completed any Steps this Worksheet is cumulative, use that document. If you have not you complete that aspect that is highlighted for your plan documentation. **Italics mean a sub plan that might be attached or live somewhere else, location of document and contact is what would go in the plan.*

I. People Design, Phase 1

   A. Shared Watershed Vision and Desired Outcomes (Step 1)

      1. Logic Model of Desired Outcomes/Results and activities/target audiences to employ to achieve outcomes

   B. Keepers of the M & A Plan (Step 1)

   C. Watershed Boundary (Step 2)

   D. Water bodies of Interest (Step 2)

   E. Scope Inventory Master List* (Step 2)

      1. Physical Inventory * (Step 2)

      2. People Inventory* (Step 2)

      3. Information Inventory* (Step 2)

         a. Existing Monitoring Efforts (Step 2)

         b. Existing Data Sources (Step 2)

      4. Inventory Action Plan* (Step 2)

   F. Assessment Type(s) List – Monitoring Reason + Use (Step 3)

      1. Monitoring Question(s) (Step 4)

      2. Targeted Decision Maker(s) (Step 5)

         a. Information Needs (Step 5)

      3. Information Blue Print – Data Pathway Fact Sheet Per Monitoring Question* (Step 6)

II. Technical Design, Phase 2

   A. What (Indicators, Benchmarks, etc.) and why? (Step 7)

   B. When and why? (Step 8)

C. Where and why? (Step 9)

D. W(how) will meet data quality objectives? (Step 10)

1. Methods and Data quality objectives (Step 5 and 10)

2. Quality Assurance and Control Measures (Quality Assurance and Control Plan)* (Step 10)

E. Data Management for Raw Data (Data Management Plan Part 1)* (Step 11)

III. Information Design, Phase 3

A. Data Summary and Analyses (Step 12)

1. Starting Point (Step 12)

2. Changes (Later)

B. Data Interpretation, Conclusions, Recommendations

1. Starting Point (Step 13)

2. Changes (Later)

C. Communication and Delivery

1. Starting Point (Step 14)

2. Changes (Later)

D. Management Plans to Generate Information (Data Management Plan Part 2)* (Step 15)

IV. Evaluation Design, Phase 4

A. Who Will Do What? (Step 16)

1. Task Identification Matrix (Step 16)

2. Communication Structure and Tools (Step 16)

B. Evaluation Plans (Step 17)

1. Evaluation Plans for M & A Components (Step 17)

2. Evaluation Plans for M & A Implementation (Step 17)

3. Evaluation of inter/intra M & A Activities (Step 17)

C. Documentation and Communication (Step 18)

1. M & A Plan (**this document**, updated Sub documents) (Step 18)

2. Communication and Peer Review Plan (Step 18)

3. Action Plan* (Step 17)

For Sheet 10.8.a **Place your identified gaps and needs regarding this step in the *Action Plan* (what you need to plan to complete this step and or overall monitoring and assessment plan).**

Worksheet 10.8.a **Final *Action Plan* Part 1, Summary:**

If you have completed each Step, or for those you have, you have a cumulated list of gaps and needs related to that Step. Use that same worksheet/document. If you did not complete each Step, look at what each Step is supposed to accomplish and record what your gaps and needs are related to that topic. The goals are to get the gaps and needs in one place to evaluate and prioritize.

Phase 1 Step 1: (completed in Step 1)
Phase 1 Step 2: (completed in Step 2)
Phase 1 Step 3: (completed in Step 3)
Phase 1 Step 4: (completed in Step 4)
Phase 1 Step 5: (completed in Step 5)
Phase 1 Step 6: (completed in Step 6)
Phase 2 Step 7: (completed in Step 7)
Phase 2 Step 8: (completed in Step 8)
Phase 2 Step 9: (completed in Step 9)
Phase 2 Step 10:
Phase 3 and 4 Steps: Will add Action and Needs as complete each Step and at the end prioritize

Background and Content

Set Data Quality Objectives

- Overall Data Quality Objective
- Data Quality Objectives for Collecting Samples
- Data Quality Objectives for Analysis

There is more than one way to measure most indicators. How do you choose among the myriad methods? One of the key questions to ask is, "What quality of data do you need to produce in order to use it for your purposes?" Data quality objectives (DQOs) are statements and/or numerical descriptions of the benchmarks you set for your sampling and analysis methods. While data quality objectives are not your only consideration, they can help you identify the methods that most closely match your needs.

In this section, we'll briefly review some of the basic concepts. EPA has produced detailed guidance for developing data quality objectives. Data quality objectives serve two purposes:

1. Before you collect any field data, they help you select appropriate methods.
2. After you've begun collecting field data, they help you track whether the methods are working.

Setting data quality objectives before you've gathered field data may be the most challenging step in the assessment process. In part, it's a "chicken-and-egg" situation because it is difficult to know whether the objectives are reasonable before you've taken any measurements. You may decide to collect measurements during a "testing phase" to establish a record of whether your methods can meet your DQOs. You can also consult with other tribes or agencies, to see if their experience can help you set reasonable objectives.

> **A word of caution:** As of this writing, most of the guidance for setting data quality objectives is aimed primarily at collecting and analyzing samples of chemical indicators in the water itself. Some methods, such as those that involve observation, may not lend themselves to numerical objectives.

You may not need to set data quality objectives. Three reasons to set DQOs include:

1. You are using federal funds and preparing a QAPP-DQOs are required.
2. You are letting others use your data and they require DQOs.
3. You want to collect data of a particular quality.

> EXAMPLE:
>
> Suppose you want to evaluate the impact of an upstream municipal wastewater treatment plant on tribal waters. Your overall data quality objective might be:
>
> **To produce data that the tribe can use to determine whether the treatment plant is impairing aquatic life and ceremonial uses of tribal waters.**

Data quality objectives are an integral part of a Quality Assurance Plan (QAP), which may be required if you are using federal money for monitoring (See section 3 of this chapter). In a QAP, you set up quality control checks. These checks are designed to test your sampling and analytical processes, and produce data which you compare with your objectives.

Overall Data Quality Objective

Before developing specific objectives, it's usually helpful to come up with an overall objective that describes how you will use the data. This can be a simple narrative statement.

Your data quality objectives will describe in more detail how you will meet this overall objective. Detailed DQOs will help you select the right methods, both for collecting samples and analyzing them.

Data Quality Objectives for Collecting Samples

Data quality objectives for sampling describe your targets for:

> **Completeness**: How many measurement samples will you need for a complete data set? You need to consider the overall number of samples needed, as well as the number needed at particular sites and under any different conditions dictated by your study question.
>
> **Representativeness**: How many samples will you collect, and where will you collect them to ensure that they represent the actual environmental condition or population you are sampling? This is important because, in most cases, you are only sampling a very small part of the watershed.
>
> the appropriateness of your sampling site selection for describing the general characteristics of the water body and specific impacts.
> the appropriateness of the location of the sample collection point: spatial location (mid-stream, mid-lake, etc.), sampling depth, number of sites, etc.
> the appropriateness of the parameters to the type of impact. Later sections evaluate these issues in greater detail and should be consistent with the statement here.
>
> **Comparability**: How comparable will your data be to previously collected data? There are statistical methods for setting data quality objectives for sampling, but they are beyond the scope of this guide.

Data Quality Objectives for Analysis

Analysis is the process of measuring the indicators you've chosen. Measurements can be done in the field (for example, by using a field meter) or the lab. Data quality objectives for analysis describe the quality targets you must hit in order to provide useful data.

> **Precision** is the degree of agreement among repeated measurements of the same indicator and gives information about the consistency of your methods.
>
> **Accuracy or Bias** is a measure of confidence that describes how close a measurement is to its ‘”true” value.
>
> **Measurement Range** is the range of reliable readings of an instrument or measuring device in actual use on real samples; both the upper and lower limits that you might expect must be considered. To help in determining the measurement range for your project and also help you

to properly select methods or instruments that will meet your needs, your measurement range should reflect the part of the total "expected" range that your study will encounter, and your methods or instruments should provide a detection limit that can properly measure that range.

Detection Limits include several different types, and it is important to understand the difference because it affects your choice of methods and instruments. Only the Method Detection Limit (MDL) or Practical Quantitation Limit (PQL) is relevant for your QAPP, but you will probably encounter the others in product specifications or other studies. Since the other limits provide a rosier picture of the method or instrument capabilities, it is extraordinarily important for your project that you make sure your MDL or PQL matches the measurement range.

Instrument detection limit (IDL) is three times the standard deviation above the instrument noise level, for practical purposes the lower limit of the indicator that the instrument is capable of detecting. This is the value commonly reported in instrument advertisements.

Lower level of detection (LLD) is the level of measurement that can be reproduce with 99% certainty, everything else remaining constant. It is typically twice the IDL.

Method detection limit (MDL) is the level of measurements that can be reproduced with 99% certainty after going through the entire analytical method by an experienced operator. It is typically four times the IDL. Reporting Detection Limit (RDL) is sometimes used synonymously with MDL.

Practical quantitation limit (PQL) that is the level that several labs can achieve using the same samples. The PQL is customarily about four to five times the MDL or ten times the IDL.

For most instrument specifications, IDL is reported. For most methods, MDL is reported.

The question for your project is whether the MDL or PQL (if you use more than one lab for the same analysis) matches or is lower than the lowest value of your expected range for each parameter, reporting limit requirements, action limit, or regulatory requirements as set by federal or state agencies. For example, if you need to determine total phosphate values as low as 0.005 mg/l (5 ppb), the MDL or PQL must be 0.005 mg/l or lower. QAPP reviewers will check that your methods and instruments are appropriate for your target measurement range .

Example Data Quality Objectives for Typical Indicators Measured by Volunteers in Massachusetts.[1]

These example DQOs are based on the range of analytical methods and field/lab instrumentation available to volunteers, and on historical results for quality control samples, where available. Each volunteer group must determine project goals, select project-based equipment, assess field and lab capabilities, and review historical quality control data, in order to choose reasonable project-specific data quality objectives.

Indicator	Units	Minimum Detection Limit	Accuracy/Bias (1,2)	Overall Precision (3)	Approx. Potential Range
DO	mg/l	0.0	+0.5 for zero standard	<0.5 difference between dups	0.0-15.0
BOD	mg/l	0.0	Within lab control limits for glucose-glutamic acid and dilution water blank checks	<1.0 difference between dups	0.0-10.0
Temperature	°C	0.0	±0.5 °C in comparison to NIST-traceable thermometer	+/- 0.5 °C	0.0-30.0
Conductivity	µS/cm	25	±5% of known QC std.	10% RPD	10-2000 (freshwater)
pH	pH units NA	+0.2	of QC standard	± 0.2	4.0-10.0
TP (water)	mg/l P	0.005	80-120 % recovery for QC std. and lab fortified matrix	± 0.005 mg/l if less than 0.050 mg/l or 20% RPD if more than 0.050 mg/l	0.000-0.500
Alkalinity	mg/l CaCO3	-5.0	80-120 % recovery for QC std. and lab fortified matrix	± 2.0 mg/l if less than 20 mg/l or 20% RPD if more than 20 mg/l	-5.0 to 150.0
Ammonia Nitrogen	mg/l N	.010	80-120 % recovery for QC std. and lab fortified matrix	± 0.01 if less than 0.1 mg/l or 20% RPD if more than 0.1 mg/l	0.00-1.0
Nitrate Nitrogen	mg/l N	.010	80-120 % recovery for QC std. and lab fortified matrix	± 0.02 if less than 0.1 mg/l or 20% RPD if more than 0.1 mg/l	0.00-2.0
Kjehldahl Nitrogen	mg/l N	.025	80-120 % recovery for QC std. and lab fortified matrix	± 0.20 if less than 0.5 mg/l or 20% RPD if more than 0.5 mg/l	0.00-2.0
Secchi disk Transparency	m	0.2	NA	± 0.2 m for duplicate readings by the same monitor, as well as different monitors.	0.0-10.0
Color	PCU	5	80-120 % recovery of color standard	± 10 PCU if less than 50 PCU or 25 % RPD if more than 50 PCU	0-500
Turbidity	NTU	5	90-110% recovery of turbidity std.	± 5 NTU if less than 1 NTU or 20% RPD if more than 1 NTU	0-200

[1] Godfrey, Paul, Jerome Schoen, and Geoff Dates, 2001. The Massachusetts Volunteer Monitor's Guidebook to Quality Assurance Project Plans, MA Department of Environmental Protection, Worcester MA.

Indicator	**Units**	**Minimum Detection Limit**	**Accuracy/Bias (1,2)**	**Overall Precision (3)**	**Approx. Potential Range**
Salinity	SU	0.1	80% -120% recovery of seawater standard of known conductivity	20% RPD	0.0-40.0
Total Suspended Solids, TSS	mg/l	0.01	75-125 % recovery for QC std.	± 1.0 or 25% RPD whichever is higher	0.0-500
Total Dissolved Solids, TDS	mg/l	0.01	75-125 % recovery for QC std.	± 1.0 or 25% RPD whichever is higher	0.0-500
Chlorophyll *a*	µg/l	1.0	75-125 % recovery for QC std.	± 2.0 if less than 15 µg/l or 25% RPD if more than 15 µg/l	0.0-100
Hardness	mg/l	1.0	80-120 % recovery for QC std. and lab fortified matrix	20% RPD	0-100
Fecal Coliform, Enterococcus, E-coli	# of colonies/100 ml	0	"TNTC" on positive control and/or less than reporting limit for negative control	30% RPD for log 10 transformed duplicate data	0-100,000
Macrophyte% Cover Map	% area	5	NA (if true % cover were known, results would be expected to be +/- 20%)	NA	0-100%
Macrophyte Identification	NA	NA	Qualitative assessment by aquatic plant experts by spot checking/testing the accuracy of identification using the same plants.	Qualitative assessment based on same-plant identifications by other volunteers in the same group.	NA
Macroinvertebrates (taxonomy)	NA	NA	Qualitative assessment based on spot checks for taxonomic accuracy using the same samples, by macroinvertebrate experts.	Qualitative assessment based on same-sample identification by other volunteer taxonomists in the same group.	NA
Flow (not generally recommended for volunteers to take)	cfs	NA	NA (based on studies using known flows, generally excepted to be 80% - 120% of true flow for scientific staff using best available equipment. For volunteers, the estimated expected accuracy would be reduced significantly (ex. 50-150% or worse)).	35% RPD, based on duplicate flow measurements taken sequentially by two separate volunteers using the same equipment (ex. velocity meter/depth rod, bucket/watch for pipe flows).	0-100 for lo flows potentially sampled by volunteers

[1] Accuracy is determined by the analysis of spiked sample except as noted in the table. QC sample recoveries may also be used to assess accuracy when spiked sample analysis is not possible. The general DQO for all analyte blanks is no exceedances of the MDL.

[2] For accuracy determination, spiked samples are preferred

[3] Overall precision is measured using the relative percent difference, RPD (or std. deviation for n>2) of field duplicate samples. Lab precision is based on an estimate of the RPD between duplicate aliquots of the same lab sample. If the same lab sample is split to two or more labs for analysis, a measure of inter-lab precision can be made.

[4] Contact MWWP, MADEP or EPA-NE for additional specific experience.

Revisit your data quality objectives after your first round of data collection. Did you meet them? Can you meet them? Don't be afraid to adjust your data quality objectives (and possibly your goals) according to actual experience.

Once you've set your data quality objectives, the next step is to find sampling and analysis methods that are likely to meet them.

Basic Information About Analytical Methods

This section describes the basic laboratory methods used to analyze water samples. These methods are referred to in the next section on methods for each indicator.

> **Titration**: Determining the concentration of an indicator in a sample by adding to it a standard reagent of known concentration in carefully measured amounts until a color change or electrical measurement is achieved, and then calculating the unknown concentration. Common indicators measured this way are dissolved oxygen and alkalinity.
>
> **Colorimetric**: Determining the concentration of an indicator in a sample by adding to it a reagent that causes a color change in direct proportion to the concentration of the indicator being measured. The intensity of the color (as measured by the extent to which it absorbs or transmits light) is either read with a visual color comparator or measured using a meter and either read directly in appropriate reporting units or read in "% absorbance" or "% transmittance" units and converted to reporting units. Common indicators measured this way are nutrients.
>
> **Electrometric**: Determining the concentration of an indicator in a sample by using a meter with an attached electrode which measures the electric potential (millivolts) of the sample. This amount of electric potential is a function of the activity of ions or molecules in the sample and proportional to the concentration of the indicator being measured. The electrode is selected based on its response to specific ions (known as an "Ion Selective Electrode" (or ISE), general ionic activity (conductivity) or molecules (for example, a Membrane Electrode). The meters can either display results in either millivolts (mV) or in appropriate reporting units. Common indicators measured this way are dissolved oxygen, pH, conductivity, and nutrients.
>
> **Gravimetric**: Determining the concentration of an indicator in a sample by filtering a specified quantity of the sample and determining the weight of the material retained on the filter. Common indicators measured this way are total solids and total suspended solids.
>
> **Nephelometric**: Determining the clarity of a sample by measuring the intensity of light scattered by particles in the sample and comparing this with a known solution. The higher the intensity of the scattered light, the higher the turbidity, reported in nephelometric turbidity units (NTU's).
>
> **Membrane Filtration and Incubation**: Determining the bacteria concentration of a water sample by filtering a specified quantity through a specified gridded membrane filter, which retains the bacteria and other particles larger than 0.45 microns. After filtration, the membrane containing the bacterial cells is placed on a specific nutrient medium and then incubated at a

specified temperature for a specified length of time. Colonies of a specified color growing on the filter are then counted.

Selecting Methods for Assessment

Please refer to the table: "Assessment Tables." From here, you will be able to start selecting methods. The table allows you to:

- Examine how the indicators relate to your monitoring question
- Compare basic examples of different methods for each indicator or parameter
- Relate those method choices to data use
- Factor in basic expectations (of time, initial costs, and on-going costs) for those methods

Scientific Considerations in Selecting Methods

Here are some things to consider when selecting methods:

- Does it meet your data quality objectives?
- How accurate is it?
- How precise (reproducible) is it?
- What is its detection limit?
- Will it measure the indicator in the range that you need?
- What lab facilities are required?
- What equipment is required?
- Does it yield samples that are representative?
- Is it comparable to methods used by agencies collecting similar information?

Practical and Program Considerations in Selecting Methods

- Do you have the human and financial resources to do it?
- How difficult is it?
- How time-consuming is it?
- Will it produce data useful to the target audience?

Following is a description of the analytical methods used for each indicator/ parameter:

ACIDITY

Acidity is the water's ability to resist a change in pH when a base is added. This is largely caused by carbon dioxide, salts of strong acids and weak bases, and other factors. Above a pH of 8.3, there is no measurable acidity. Acidity is the reverse of the alkalinity buffering effect. It is measured as the concentration of $CaCO_3$.

Analytical Methods: Acidity is measured by titrating a sample to either 3.7 (methyl orange acidity using bromphenol blue indicator) or 8.3 phenolpthalein acidity using penolpthalein indicator). Acidity (in mg/L as $CaCO_3$) is calculated from the amount of titrant (sodium hydrozide) needed to bring the sample to either pH.

ALKALINITY, TOTAL:

This is a measure of the water's ability to neutralize acids -- the higher the alkalinity levels, the more acid-neutralizing capacity the water has. This is important for aquatic ecosystems because it protects against changes in pH, which can harm aquatic life.

Analytical Methods: Basic Methods use titration. Advanced Method uses a meter to measure the pH at two endpoints

Basic Method	Advanced Method
Sulfuric Acid Titration w/ Bromcresol Green/Methyl Red - the sample is collected and treated with bromcresol green-methyl red. - It is then titrated with sulfuric acid until the solution turns pink. - The amount of acid added to reach this point is converted to total alkalinity.	***Double End Point Sulfuric Acid Titration w/ pH Meter*** - the sample is collected and the pH measured - It is then titrated with sulfuric acid until the pH is 4.5, the 4.2. - The amount of acid added to reach this point is converted to total alkalinity.

BENTHIC MACROINVERTEBRATES

Samples can be collected in many different ways:

Qualitative Net Collection: A sample is collected directly off the bottom using a net. The level of effort is not standardized.
Semi-Quantitative Net Collection: A sample is collected directly off the bottom using a net such as a D-net. The level of effort is standardized by collecting from a specified area in front of the net. Since the area is not precisely delineated, the method is not strictly quantitative.
Quantitative Collection*:* A sample is collected by using a Surber sampler or by placing rock-filled baskets on the stream bottom and allowing them to be colonized. The time the rock-filled baskets are left out is standardized at six weeks and the colonization area in each basket is roughly the same. A Hess sampler or Hester Dendy multiplate sampler can also be used in stream. Quantitative algal samples from lake water column can be collected using a plankton net of known diameter being pulled through the water column at a known speed for a known distance.

BIOCHEMICAL OXYGEN DEMAND (BOD):

BOD is a measurement of the amount of oxygen consumed by organic matter and associated microorganisms and through chemical oxidation in the water over a period of time, usually five days. Measuring the biochemical oxygen demand (BOD) of the water tells us whether oxygen demanding wastes might cause low DO levels at times.

Analytical Methods: Basic and advanced methods use a version of Winkler Titration. As with dissolved oxygen, the main difference is the type of titrator or use of a meter.

Basic Methods	Advanced Methods
Modified BOD-5 Day Method (Hach via Mitchell & Stapp) - Two samples are collected in glass-stoppered BOD bottles (one clear and one black) as in the DO method. - The DO is determined for the clear bottle, using Modified Winkler Titration with a syringe or eyedropper. - The black bottle is placed in the dark and incubated for five days at 68°F. - The DO for this sample is then determined the same way. - BOD is determined by subtracting the DO level of the black bottle from the clear bottle.	***Modified BOD-5 Day Method w/ modified Winkler Titration or Meter (Standard Methods #521 O-B or equivalent)*** - Two samples are collected in glass-stoppered BOD bottles (one clear and one black) as in the DO method. - The DO is determined for the clear bottle, using Modified Winkler Titration with a buret, syringe, digital titrator:, or meter - The black bottle is placed in the dark and incubated for five days at 68°F. - The DO for this sample is then determined the same way. - BOD is determined by subtracting the DO level of the black bottle from the clear bottle.

CHLOROPHYLL A:

Chlorophyll a is a green pigment found in all plants. It is used to quantify the abundance of algae in water. When chlorophyll a degrades, it converts to pheophytin. The ratio of chlorophyll a to pheophytin is used to determine the health of the algae sampled.

Analytical Methods: Measuring chlorophyll a involves a sophisticated process for which there are no simple methods.

Basic Methods	Advanced Methods
None	***Pigment extraction followed by spectrophotometry (Adapted by Paul Godfrey from Standard Methods #10200 H)*** - Collect an integrated water sample using a clean container (at least one qt). - Filter subsample (quantity depends on a secchi reading) using a glass fiber filter and vacuum pump. - Analyze filters immediately, frozen, or dried. - Extract pigment by grinding the filter, steeping the ground mass in 90% acetone, and centrifuging in tubes to de-suspend fibers from the solution. - Read color with a spectrophotometer and calculate concentration. - Add hydrochloric acid to the sample to convert all chlorophyll to pheophytin. - Read color again with a spectrophotometer and calculate the concentration of pheophytin.

CHLORINE, TOTAL RESIDUAL

Chlorine is a gas in its natural state. It is toxic to microbes and animals and is widely used to disinfect drinking water and wastewater. It can also combine with a wide variety of organic and inorganic chemicals to produce toxic compounds. It does not appear to be toxic to humans, except when it combines with other compounds. Total Residual Chlorine consists of Free Chlorine (hypochlorite ion, hypochlorous acid – the disinfecting agent) and chloramines (formed when chlorine reacts with ammonia or nitrogen).

Analytical Methods: Amperometric Titration: Chlorine is tricky to sample because it is volatile (tends to convert to gas quickly) and has tricky flow patterns. We recommend consulting with your regional DEP biologist. The analytical method involves titrating a prepared sample with Phenylarsine Oxide sing an Amperometrc Titrator to an endpoint.

CONDUCTIVITY:

This is a measure of the water's ability to pass an electrical current. This ability depends on the presence of inorganic dissolved solids made up of ions (particles that carry a positive or negative electrical charge). Since it measures a wide range of materials, its primary importance is as an indicator of general pollution, rather than a specific pollutant.

Analytical Methods: Basic and advanced methods use a conductivity meter. This meter contains a probe with two electrodes. The probe is lowered into the water, voltage applied, and the drop in voltage caused by the resistance of the water is measured and converted to conductivity. The basic method uses a relatively inexpensive "pen." The advanced method uses a high-quality meter to measure the pH at two endpoints.

Basic Methods	Advanced Methods
Electrometric Using A Conductivity Pen - Collect water sample or measure directly with pen. - Measure collected sample with pen	***Electrometric Using A Conductivity Meter (EPA Method 120.1)*** - Collect water sample or measure directly with meter. - Measure collected sample with meter.

DISSOLVED OXYGEN (DO):

DO is the presence of oxygen gas molecules in the water. Since it is critical to many biological and chemical processes in the water and essential for aquatic life, dissolved oxygen is an indicator of the capability of the aquatic ecosystem to support life.

Analytical Methods: Basic and advanced methods use a version of Winkler Titration. The main difference is the size of the increment of titrant added to the sample – smaller increments increase sensitivity.

Basic Methods	Advanced Methods
Modified Winkler Titration w/ a syringe or eyedropper (Hach via Mitchell & Stapp) This is essentially the Modified Winkler Titration described above, with some changes. The titrant is phenylarsine oxide solution and the titrator is an eyedropper. The eyedropper gives less accuracy and sensitivity than other titrators because it dispenses larger drops -- each drop equals 0.5 mg/l.	***Modified Winkler Titration w/ a buret, syringe, or digital titrator: Standard Method #4500-OG (or equivalent)*** - Collect surface samples in 300 mL "BOD" bottles with glass stoppers so that no air bubbles are trapped. In lakes, an integrated sample is collected using a length of garden hose. - Samples must be analyzed immediately or fixed and analyzed within 8 hours. - The level of oxygen in the sample is "fixed" by adding reagents which produce a chemical reaction producing iodine in direct proportion to the amount of oxygen in the water. - Sodium thiosulfate is then added incrementally using a digital titrator (Hach) or syringe (Lamotte). The amount of sodium thiosulfate it takes to turn the solution clear is proportional to the amount of iodine (which has taken the place of the oxygen) in the sample.
	Meter (Membrane Electrode) Method: Standard Methods #4500-OG (or equivalent) - A membrane-covered electrode probe is lowered into the water. - The meter electronically measures the diffusion of oxygen from the water across a membrane-covered electrode, which is directly proportional to the DO concentration.
Notes On Methods: - Water samples for dissolved oxygen should be collected in glass-stoppered BOD bottles or some other container designed so that no air is trapped in the sample. - If you have a limited budget for this indicator (<$300), we recommend that you use the Hach or Lamotte Adaptation of Winkler Titration. The Hach digital titrator dispenses smaller increments of the sodium thiosulfate than the Lamotte syringe and therefore increases the sensitivity. But, it's more expensive. - If you have the budget ($600-800) to purchase a meter and you need frequent (or continuous) measurements from a few sites, a meter will work best. However, if you have a large number of sites and can only use one meter, we recommend titration.	

FECAL COLIFORM AND E. COLI BACTERIA:

Fecal coliforms and *E. coli* are bacteria that are common in the intestines and feces of warm-blooded animals. They are used both as an indicator of the presence of sewage or animal manure in the water and as an indicator of the health risk of swimming and other water contact recreation. Fecal coliforms are the indicator used in Pennsylvania's water quality standards, *E. coli* (a species of fecal coliforms) are used in other states, per their water quality standards.

Analytical Methods: The basic methods will either detect the presence of bacteria (but don't give you a count) or they give you an estimate of density (but not a reliable count). Advanced methods are EPA-approved and give reliable counts. The most reliable count is produced by the mTEC method. Note that the mColiBlue method does not identify fecal coliforms. E. coli colonies are used as the equivalent, but these counts will underestimate fecal coliforms.

Basic Methods	Advanced Methods
Estimates of Density These methods estimate the number of bacteria in a sample in various ways: - Easygel: Using one subsample size, usually 1-5 mL, bacteria are grown on nutrient medium without filtration. Colonies of specified color are counted. Estimates total coliforms and E. coli. Fecal coliforms are estimated using E. coli counts. - Colilert: A reagent is added to various subsample sizes, which turns yellow if colifomrs are present and fluoresces if they are E, coli. A statistical table is used to estimate density based on which subsamples turn yellow and/or fluoresce.	***Fecal coliforms and E. coli: Membrane Filtration Using mTEC: EPA Method #1103.1*** - Collect water sample in sterile container - Filter several subsample sizes through 0.45 micron filters - dry incubate on mTEC nutrient medium in petri plates at 35°C for 2 hours - incubate at 44.5°C in a water bath for 22 hours. - Count fecal coliforms after incubation. - Incubate at room temperature for 20 minutes on a urea solution and count E. coli.
Presence-Absence These methods detect the presence of selected bacteria types by whether or not bacteria grows on the plate (as detected by a certain color) or whether a special broth turns color when exposed to sample water. These methods tell you bacteria is present, but not how many are there	***Fecal Coliforms: Membrane Filtration Using mFC: Standard Methods #9222 D*** - Collect water sample in sterile container - Filter several subsample sizes through 0.45 micron filters - incubate at 44.5°C in a water bath for 24 hours on mFC nutrient medium in petri plates - Count fecal coliforms after incubation.
	Fecal Coliforms: Membrane Filtration Using mColiBlue24 (Hach) - Collect water sample in sterile container - Filter several subsample sizes through 0.45 micron filters - incubate at 44.5°C in a water bath for 24 hours on mColiBlue nutrient medium in petri plates - Count E. coli colonies after incubation (use to estimate fecal coliforms).

HABITAT is typically sampled in one of two ways:

- Visual estimates of each of the habitat characteristics; or
- Field measurements of each of the habitat characteristics.

Public health is sampled for exposure and for the incidence of disease.

HARDNESS

Hardness is a measure of the calcium and magnesium positively charged ions in the water. These ions reduce the surface tension of the water, and soap does not produce lather in hard water. When hardness is primarily calcium, it is closely related to alkalinity. Hardness frequently reduce the impacts of metals on aquatic life: the higher the hardness, the lower the toxicity. Hardness is reported as mg/l of $CaCO_3$ at a given pH.

Analytical Methods: There are no basic methods. The advanced method involves either a titration or calculating the hardness from previously-determined calcium and magnesium concentrations.

Basic Methods	Advanced Methods
None	***EDTA Titration Method (Standard Method 2340C, EPA Method 130.2)*** - Collect water sample - Add dye (EBT indicator) which turns sample purple. - Titrate with EDTA reagent until solution turns blue. - Calculate hardness from amount of titrant used as $CaCO_3$

NITROGEN:

Nitrogen is a gas in the atmosphere. It combines with oxygen or hydrogen to produce various compounds -- ammonia, nitrates, and nitrates. It is an essential nutrient for plant growth and metabolic reactions in plants and animals. Together with nitrogen, it is the primary source of food energy in the aquatic ecosystem. Too much of certain forms of nitrogen can cause too much biological activity and cause undesirable effects. It is also toxic to babies in high concentrations. Nitrogen occurs in various forms, both organic and inorganic in the water, some of which are more available for plant growth than others. In some waters, nitrogen is the nutrient in short supply, so that relatively small amounts can cause impacts. Three forms of nitrogen are recommended as indicators in this handbook: ammonia, nitrates, and total. Their descriptions and methods follow:

NITROGEN - AMMONIA NITROGEN:

Ammonia (NH_3 -) is produced when organic nitrogen and/or urea break down. It is a byproduct of sewage decomposition. It is naturally present in surface waters, and can be toxic to aquatic life at relatively low concentrations (<1.0 mg/l).

Analytical Methods: Measuring ammonia involves a sophisticated process for which there are no simple methods. The Hach adaptation is the easiest, though it uses the distillation step only if known interferences are present.

Basic Methods	Advanced Methods
None	***Distillation followed by Nesslerization (Standard Methods #4500-NH3 C or equivalent)*** - Add borate solution to sample for buffering - Distill[2] sample using a distillation apparatus. This removes certain interferences. - Nesslerization. This involves pretreatment to remove turbidity-producing compounds and adding a Nessler reagent. - This produces a yellow to brown color that is measured with a spectrophotometer. - The reading is compared with a set of standard concentrations and reported as mg/l NH_3 -N.

NITROGEN - NITRATE NITROGEN:

Nitrate (NO_3 -) is produced naturally by nitrogen-fixing plants and lightning acting on atmospheric nitrogen or ammonia. Nitrate is a form of nitrogen readily used by plants. In excess, it can cause excessive biological activity in surface waters and can be toxic to infants.

Analytical Methods: Basic and advanced methods use a variation on the same procedure, except that in the basic method the color is read using a visual color comparator. In the advanced method, the color is read using an electronic meter.

Basic Methods	Advanced Methods
Cadmium Reduction followed by Color Comparator (Hach via Mitchell & Stapp) - A cadmium reduction reagent is added to a water sample. This causes a chemical reaction and turns the sample yellow-orange. - The sample color is matched to colors labeled in pH units on a color comparator. - The analyst determines the closest color match and records the nitrate concentration.	***Cadmium Reduction followed by spectrophotometry (Standard Methods #4500-NO_3- E or equivalent)*** - A cadmium reduction reagent is added to a water sample. This causes a chemical reaction and turns the sample yellow-orange. - This color is measured with a spectrophotometer. - The reading is compared with a set of standard concentrations and reported as mg/l NO3 -N.
Notes on Methods: The basic method should be considered an approximation only. This method is not acceptable for federal and state agency assessment, but is fine for education and awareness and some community assessments.	

[2] Distillation involves boiling the sample and collecting the steam.

NITROGEN - TOTAL KJELDAHL NITROGEN (TKN):

This refers to the total of organically bound nitrogen and ammonia. By analyzing samples for both ammonia and total Kjeldahl nitrogen, organic nitrogen can be calculated. This enables you to estimate how much nitrogen in the system is in organic form, intermediate form (ammonia) and inorganic form (nitrate). It may tell you how much comes from sewage, versus fertilizer, for example.

Analytical Methods: Measuring TKN involves a sophisticated process for which there are no simple methods. The Hach adaptation is the easiest, though it uses the distillation step only if known interferences are present.

Basic Methods	Advanced Methods
None	***Digestion followed by Nesslerization followed by spectrophotometry (Standard Methods #4500-Norg B or equivalent)*** - Digest[3] water sample to convert organic and ammonia compounds to ammonia nitrogen. - Ammonia is then measured using the Nesslerization Method (see ammonia methods). - The reading is compared with a set of standard concentrations and reported as mg/l TKN.

PH:

pH is a measure of the acidity of the water. Since pH affects many biological and chemical reactions in the water and most organisms have a preferred range, it is a good indicator of capability of the aquatic ecosystem to support life.

Analytical Methods: Basic methods use colorimetry. The advanced method uses a meter.

Basic Methods	Advanced Methods
Colorimetric Method (Hach via Mitchell & Stapp) - This method involves the addition of pH indicator solution to a water sample which changes color according to the pH. - The sample color is matched to colors labeled in pH units in a color comparator. - The analyst determines the closest color match and records the pH. This should be considered an approximation only.	***Electrometric Method (EPA Method 050.1 or Equivalent)*** - Collect sample or measure directly with a meter - Measure on a collected sample using a laboratory-quality meter with an electrode suitable for ionic-strength of waters. - There are less expensive pH pens or "pocket pals" on the market. These should be checked against a reliable, laboratory-quality meter to establish accuracy and precision.
pH Paper This is similar to the colorimetric method, except that a specially coated paper is dipped in the sample and turns color according to the pH. This should be considered an approximation only.	
Notes on Methods: - For waters that are low in ionic strength, accurate pH measurements require a probe that will respond in these types of waters. - pH samples should be collected so that no air is trapped in the sample. - The colorimetric method is subject to variation in the light source and the judgments of the analyst. It is inherently imprecise.	

PHOSPHORUS:

Phosphorus is an essential nutrient for plant growth and metabolic reactions in plants and animals. Together with nitrogen, it is the primary source of food energy in the aquatic ecosystem. Too much phosphorus can cause too much biological activity and cause undesirable effects. Phosphorus occurs in various forms in the water, some of which are more available for plant growth than others.

[3] The process of disintegration by means of chemical action, heat, and/or moisture.

PHOSPHORUS - TOTAL ORTHOPHOSPHATES:

This is primarily the dissolved and most available form. It is a good indicator of enrichment from various sources, such as sewage, manure, or fertilizer.

Analytical Methods: Basic and advanced methods are basically the same colorimetric method. The main difference is that the advanced method measures the color of the treated sample using an electronic instrument.

Basic Methods	Advanced Methods
Ascorbic Acid Method - Collect a sample in a phosphorus-free container. - Analyze by adding ascorbic acid reagent which turns the sample blue (ascorbic acid method) in proportion to the amount of phosphorus in the sample. - Compare this blue color to various shades using a visual color comparator to get a concentration.	***Ascorbic Acid Method (EPA Method #365.2 or equivalent)*** - Collect a sample in a phosphorus-free container. - Analyze by adding ascorbic acid reagent which turns the sample blue (ascorbic acid method) in proportion to the amount of phosphorus in the sample. - Measure the intensity of this blue color using a spectrophotometer or colorimeter and compare with results for a set of standard concentrations.
Notes on Methods The basic method should be considered an approximation only. This method is not acceptable for federal and state agency assessment, but is fine for education and awareness and some community assessments.	

PHOSPHORUS, TOTAL

Total phosphorus includes all the forms. It is a good indicator of enrichment from various sources, such as sewage, manure, or fertilizer.

Analytical Methods: Basic and advanced methods are basically the same colorimetric method. The main difference is that the advanced method measures the color of the treated sample using an electronic instrument.

Basic Methods	Advanced Methods
Persulfate Digestion Followed by Ascorbic Acid Method Collect a sample in a phosphorus-free container. Boil, acidify, and oxidize a sub-sample to convert all forms of phosphorus to orthophosphate (persulfate digestion). Analyze Orthophosphate by adding ascorbic acid reagent which turns the sample blue (ascorbic acid method) in proportion to the amount of phosphorus in the sample. Compare this blue color to various shades using a visual color comparator to get a concentration.	Persulfate Digestion Followed by Ascorbic Acid Method (EPA Method #365.2 or equivalent) Collect a sample in a phosphorus-free container. Boil, acidify, and oxidize a sub-sample to convert all forms of phosphorus to orthophosphate (persulfate digestion). Analyze Orthophosphate by adding ascorbic acid reagent which turns the sample blue (ascorbic acid method) in proportion to the amount of phosphorus in the sample. Measure the intensity of this blue color using a spectrophotometer or colorimeter and compare with results for a set of standard concentrations.
Notes on Methods: The basic method should be considered an approximation only. This method is not acceptable for federal and state agency assessment, but is fine for education and awareness and some community assessments.	

PHOSPHORUS, TOTAL DISSOLVED

Total dissolved phosphorus includes all the forms after a sample is filtered. It is a good indicator of the available forms from various sources, such as sewage, manure, or fertilizer.

Analytical Methods: Basic and advanced methods are basically the same as the method for total phosphorus, with the addition of filtering the sample before digestion and analysis.

SOLIDS:

Solids include materials that are dissolved, suspended, or settled in the water column. *Total solids* include all of these.

SOLIDS - TOTAL SUSPENDED:

Total suspended solids consist of solids that are filtered out of a water sample. Suspended solids affect water clarity and can reduce photosynthesis and cause higher temperatures.

Analytical Methods: Measuring total suspended solids involves a sophisticated process for which there are no simple methods.

Basic Methods	Advanced Methods
None	Gravimetric Method: Total Suspended Solids Dried at 103-105° C (Standard Methods #2540D) weigh a glass fiber filter filter a sample through the filter, and transfer it to a Gooch crucible. Dry filters and crucibles in an oven at 103-105°C for an hour. Weigh filters and crucibles again. Calculate total dissolved solids by subtracting the weight of the filter and crucible from the weight after filtering and drying. Results are reported as mg/l.

SOLIDS - TOTAL DISSOLVED:

Dissolved *solids* include various ions of calcium, chlorides, nitrate, phosphate, iron, sulfur and others that will pass though a two-micron pore. These affect the water balance in the cells of aquatic organisms, making it difficult for them to maintain position in the water column.

Basic Methods	Advanced Methods
None	***Gravimetric Method: Total Dissolved Solids Dried at 180°C (Standard Methods #2540C)*** - Filter a sample through a glass fiber filter - weigh a ceramic dish - pour the filtered sample into the dish - evaporate the water in an oven at 180°C, and weighing the dish plus residue. - Calculate total dissolved solids by subtracting the weight of the dish from the weight of the dish with residue. Results are reported as mg/l.

SECCHI DEPTH TRANSPARENCY (for lakes only):

Transparency describes scattering and absorption of light by small particles and molecules in the water. This is most commonly expressed as the depth at which a black and white patterned device known as a *secchi disk* disappears from sight. The more transparent the water, the lower the depth at which the disk disappears. Reduced transparency has the same effects as elevated turbidity.

Basic Methods	Advanced Methods
Secchi Disk - Lower secchi disk into the water until it disappears from sight - Bring disk up until it appears again. - The average of these two depths is the secchi depth transparency.	***Same as basic***

TEMPERATURE:

Since temperature affects many biological and chemical reactions in the water and most organisms have a preferred range, it is a good indicator of capability of the aquatic ecosystem to support life. It is measured in degrees Fahrenheit (°F) or degrees Celsius (°C).

Basic Methods	Advanced Methods
Direct Measurement with thermometer	***Direct Measurement with thermometer, thermocouple, thermistor or a multi-use meter***

TURBIDITY (for streams only):

Turbidity describes how the particles suspended in the water affect its clarity by scattering light. It is an indicator of the presence of suspended sediment from erosion, which can decrease biological activity, raise water temperatures, and clog fish gills and gravel spawning areas. Turbidity results are usually reported as nephelometric turbidity units (NTUs).

Analytical Methods: The basic methods involve measuring transparency, which includes both light scattering and absorption. The advanced method measures just light scattering. Thus, the results of basic and advanced methods are not comparable with each other. The "advanced" method is actually fairly simple, though it involves an expensive meter.

<table>
<tr><th>Basic Methods</th><th>Advanced Methods</th></tr>
<tr><td>Turbidity Tubes (Lamotte)
- Two graduated cylinders with black dots on the bottom are filled to a specific volume -- one with sample water the other with turbidity-free water.
- A reagent is added to the turbidity-free water cylinder, until the visibility of the dot on the bottom is equivalent to that of the cylinder with the sample.
- The results are reported in unspecified units.
- This method actually measures absorbance plus scattering, so the results are not actually NTUs.</td><td>Nephelometric Method (Standard Methods #2130 or equivalent)
- Turbidity is measured by collecting and analyzing a water sample using a nephelometer.
- A nephelometer consists of a light source that projects a beam of light through the water sample and a photo-electric cell that measures the intensity of light scattered by particles at a 90° angle from its original path.
- The results are reported as nephelometric turbidity units (NTUs).</td></tr>
<tr><td>Turbidity Tube (Tennessee Valley Authority)
- These tubes are marked in increments of NTUs on the side and a wave pattern on the bottom.
- The sample is poured into the tube until the wave pattern disappears.
- The NTU increment level of the sample is reported.
- This method actually measures absorbance plus scattering, so the results are not actually NTUs. In fact, they should be reported in centimeters or inches.</td><td></td></tr>
<tr><td colspan="2">Notes on Methods
- Measure turbidity in rivers.
- Make sure that the meter you purchase is a nephelometer that measures light scattered at a 90° angle.
- Turbidity tubes are not acceptable substitutes for a nephelometer, since they actually measure transparency (light scattering and absorption), rather than just light scattering. Because of this, they are unreliable in colored waters, which absorb light, though may not be turbid at all. They are really more analogous to secchi disks, in that your eye responds to absorption. If you use these tubes, report your results as a depth (in centimeters or inches) rather than NTUs.</td></tr>
</table>

Water Column Metals and Other Elements Recommended for Sampling Only (Advanced Assessments)

Many naturally-occurring metals are toxic to aquatic life, when present in high enough concentrations. The most common process is when they bind to gill surfaces on fish and insects. The metals of concern are mostly those that are "available" as dissolved ions in the water column.

The following metals and other elements are recommended by several of the advanced assessments. However, the analysis methods require techniques and equipment are beyond the means of community-based groups and schools (except universities). Therefore, we recommend sampling only. Even for sampling, we recommend consulting with your regional DEP biologist as to sampling procedure

Sampling (Standard Methods 3010B)

Because some metals are toxic in very small amounts (micrograms per liter), the methods must be able to detect very low concentrations. Contamination of sampling containers is a real concern. Samples for metals are usually collected in special acid-rinsed containers made of polypropylene, linear polyethylene, or borosilicate glass. Samples to be analyzed for dissolved metals are immediately filtered through a 0.45 micron filter. Otherwise they are preserved by acidifying with concentrated nitric acid to a pH of <2.

Analytical Method (EPA Method 200.7)

Various forms of metals can be analyzed, depending on how the sample is treated:

- Dissolved Metals: The filtered sample is analyzed.
- Suspended Metals: Metals trapped on the filter.
- Total Metals: Metals detected in an unfiltered sample after digestion or the sum of dissolved and suspended metals.
- Acid-extractable Metals: Metals in solution after treatment of the sample with hot mineral acid.

Metals are usually analyzed as a suite using *Inductively Coupled Plasma - Atomic Emission Spectrometry*. An inductively coupled plasma source (a machine) vaporizes the sample and heats it to about 6000-8000°C. Molecules separate and atoms become active and ionized (reactive). In this state, each element produces a unique spectral (colored) pattern which is read by a spectrometer.

Needless to say, this is an extremely technical and expensive method beyond the reach of volunteer monitoring programs.

ALUMINUM (sampling only)

Aluminum is a naturally occurring element in rocks, soils, and the waters in contact with them. It occurs as a soluble salt, a colloid, or an insoluble compound. No information on aquatic life toxicity or human health effects was found as of this writing.

ARSENIC (sampling only)

Arsenic is a naturally occurring element in rocks, soils, and the waters in contact with them. Recognized as a toxic element for centuries, arsenic today also is a human health concern because it can contribute to skin, bladder, and other cancers (National Research Council, 1999).

Arsenic is widely distributed throughout the earth's crust and is used commercially, primarily in alloying agents. It is introduced into water through the dissolution of minerals and ores, from industrial effluents, and from atmospheric deposition; concentrations in groundwater in some areas are elevated as a result of erosion from local rocks

Arsenic is highly toxic, though its toxicity is dependent on its form and environmental conditions.

Used in groundwater assessment only.

BARIUM (sampling only)

Barium is a lustrous, machinable metal which exists in nature only in ores containing mixtures of elements. It is used in making a wide variety of electronic components, in metal alloys, bleaches, dyes, fireworks, ceramics and glass. In particular, it is used in well drilling operations where it is directly released into the ground.

EPA has found barium to potentially cause gastrointestinal disturbances and muscular weakness. when people are exposed to it at unsafe levels for relatively short periods of time

In water, the more toxic soluble barium salts are likely to be converted to insoluble salts which precipitate. Barium does not bind to most soils and may migrate to ground water. It has a low tendency to accumulate in aquatic life and does not seem to be an aquatic life health concern.

Used in groundwater assessment only.

CADMIUM (sampling only)

Cadmium is a metal found in natural deposits as ores containing other elements. The greatest use of cadmium is primarily for metal plating and coating operations, including transportation equipment, machinery and baking enamels, photography, television phosphors. It is also used in nickel-cadmium and solar batteries and in pigments.

EPA has found cadmium to potentially cause vomiting, diarrhea, muscle cramps, nausea, salivation, sensory disturbances, liver injury, convulsions, shock and renal failure when people are exposed to it at unsafe levels for relatively short periods of time. Cadmium has the potential to cause kidney, liver, bone and blood damage from a lifetime exposure at unsafe levels.

Cadmium occurs naturally in zinc, lead, copper and other ores which can serve as sources to ground and surface waters, especially when in contact with soft, acidic waters. Major industrial releases of cadmium are due to waste streams and leaching of landfills, and from a variety of operations that involve cadmium or zinc. In particular, cadmium can be released to drinking water from the corrosion of some galvanized plumbing and water main pipe materials.

Some cadmium compounds are able to leach through soils to ground water. When cadmium compounds do bind to the sediments of rivers, they can be more easily bioaccumulated or re-dissolved when sediments are disturbed, such as during flooding. Its tendency to accumulate in aquatic life is great in some species, low in others. Toxicity increases as hardness decreases.

CALCIUM (sampling only)

Calcium is a naturally-occurring element that enters surface water from surrounding rocks. It is a vital micro-nutrient for both plants and animals. In various compounds, calcium is an important part of the water's buffering system (see alkalinity, acidity, hardness). Used in groundwater assessment only.

CHROMIUM (sampling only)

Chromium is a metal found in natural deposits as ores containing other elements. Though chromium occurs in nature mostly as chrome iron ore and is widely found in soils and plants, it is rare in natural waters. The greatest use of chromium is in metal alloys such as stainless steel; protective coatings on metal; magnetic tapes; and pigments for paints, cement, paper, rubber, composition floor covering and other materials. Its soluble forms are used in wood preservatives.

Short-term: EPA has found chromium to potentially cause skin irritation or ulceration.when people are exposed to it at unsafe levels for relatively short periods of time. Chromium has the potential to cause damage to liver, kidney circulatory and nerve tissues; skin irritation from a lifetime exposure at unsafe levels.

When released to land, chromium compounds bind to soil are not likely to migrate to ground water. They are very persistent in water as sediments. There is a high potential for accumulation of chromium in aquatic life.

COPPER (sampling only)

Copper is a metal found in natural deposits as ores containing other elements. It is widely used in household plumbing materials.

Copper is an essential nutrient, required by the body in very small amounts. However, EPA has found copper to potentially cause stomach and intestinal distress, liver and kidney damage, and anemia when people are exposed to it at high levels for relatively short periods of time.

Copper may occur in drinking water either by contamination of the source water used by the water system, or by corrosion of copper plumbing. Corrosion of plumbing is by far the greatest cause for concern. Copper is rarely found in source water, but copper mining and smelting operations and municipal incineration may be sources of contamination.

All water is corrosive toward copper to some degree, even water termed non-corrosive or water treated to make it less corrosive. Corrosivity toward copper is greatest in very acidic water. Many of the other factors that affect the corrosivity of water toward lead can also be expected to affect the corrosion of copper.

Copper is toxic to aquatic life at high levels, though it does not appear to accumulate in the edible portions of freshwater fish. Toxicity increases as hardness decreases.

IRON, TOTAL (sampling only)

Iron is a metal common in rocks and soils and in varying quantities in surface water. It is an essential trace element required by both plants and animals. Iron is not considered a problem for aquatic life.

LEAD (sampling only)

Lead is a metal found in natural deposits as ores containing other elements. It is sometimes used in household plumbing materials or in water service lines used to bring water from the main to the home.

Lead can cause a variety of adverse health effects when people are exposed to it at unsafe levels for relatively short periods of time. These effects may include interference with red blood cell chemistry, delays in normal physical and mental development in babies and young children, slight deficits in the attention span, hearing, and learning abilities of children, and slight increases in the blood pressure of some adults. Lead has the potential to cause stroke, cancer and kidney disease from a lifetime exposure at unsafe levels.

Lead may occur in drinking water either by contamination of the source water used by the water system, or by corrosion of lead plumbing or fixtures. Lead is rarely found in source water, but lead mining and smelting operations may be sources of contamination. Corrosion of plumbing is by far the greatest cause for concern.

When released to land, lead binds to soils and does not migrate to ground water. In water, it binds to sediments. It does not accumulate in fish, but does in some shellfish, such as mussels. Toxicity increases as hardness decreases.

Used in groundwater assessment only.

MANGANESE (sampling only)

Manganese does not occur naturally as a metal. It is frequently found in various salts and minerals, frequently with iron. It is a vital micro-nutrient for both plants and animals. It occurs in surface waters in soluble or suspended form, but rarely in concentrations considered toxic to aquatic life.

POTASSIUM (sampling only)

Potassium is an abundant element found in many minerals. It is an essential plant and animal nutrient and is also common in fertilizers. Used in groundwater assessment only.

SILICA (sampling only)

Silicon is an abundant element and most waters contain it in the form of silica (SiO_2) and silicates. The chief concern is deposits on industrial equipment. Used in groundwater assessment only.

SULFATE (sampling only)

Sulfate occurs in natural waters in a wide variety of concentrations. It can occur in high concentrations in mine drainage from the oxidation of pyrite and the use of sulfuric acid.

ZINC (sampling only)

Zinc is common in natural waters, but is increased by the deterioration of galvanized pipes. It is essential to human metabolism, but can be toxic to aquatic life

Quality Control Measures

Quality control details the technical activities used to identify and control errors resulting from sampling and analysis procedures. There are two general types of quality control measures used to assess the precision and accuracy of your monitoring results:

- ✓ **Internal Quality Control Measures:** Internal quality control measures are samples collected and analyzed by project field volunteers, staff and laboratory. Most of the QC measures you choose will be internal, and the focus of your plan.
- ✓ **External Quality Control Measures:** External quality control measures are samples collected and analyzed by non-volunteers field staff and or certified laboratories that aren't normally part of your monitoring program.

How Many QC Samples?

The percentage of your samples that will be subject to a specific quality control measure is not set in stone. It will vary for a number of reasons, such as, the parameter sampled, the level of rigor you have chosen, your data user requirements, the goals of your project, etc. As a general rule of thumb, 5-10% of your samples should be quality control samples. These recommendations are starting points only. You will need to work with your technical committee and especially your primary data user to make this decision.

What Kind Should Be Collected?

Both internal and external quality control measures are taken to quantify precision and accuracy. This ensures that your data will meet defined quality standards. Don't worry about distinguishing between internal and external measures on this worksheet, but know that both are options for your plan. The choices can be overwhelming both in cost and time. So, how much is too much? Remember who you have identified as the primary data user and what is the expected data use. If data is strictly for educational purposes, extensive QC measures are probably not required. On the other hand if you are doing monitoring to assess water use for state standards, stricter QC measures are required. You'll probably be somewhere in between. Refer back to the Step 3 Exercise: Talking to Your Data User, to make note of any specific data user requirements. Some examples of quality control measures include:

Field Blanks:

A field blank is d-ionized or distilled water that is poured into a sample container in the field as if it were a lake or stream sample. This type of blank helps to determine if there is any environment/atmosphere contamination.

Evaluation of Results: The results should be at least a factor of 5 below all sample results.

Trip Blank:

A trip blank is appropriate "blank" water placed in a sample container (with appropriate preservation) prior to going out to collect samples. This type of blank helps to determine if there is any in-transit contamination of results.

Evaluation of Results: The result should be "zero" contamination.

Sampler Blank (aka rinsate or equipment blank):

a sampler blank is de-ionized or distilled that is rinsed through the sampling device, collected and analyzed. It is used to determine if the equipment was properly handled in the field. Results indicate if the field equipment is being properly cleaned between sampling sites.

Evaluation of Results: The result should be "zero" contamination. If not, you need to determine if you need to improve your field procedures and if the results are significant enough to affect the results of other samples collected that day.

Method Blank:

A method blank is de-ionized water or distilled water process like any of the other samples.

Evaluation of Results: The results should not be detected above the reporting limits. If it is detected, the analytical equipment is not accurate since it did not read the true value.

Calibration Blanks:

A calibration blank is de-ionized or distilled water processed like any of the samples and used to "zero" the instrument.

Evaluation of Results: The results of periodic checks should be "zero."

Calibration Standards:

Calibration standards are used to calibrate a meter. They consist of one or more "standard concentrations" (made up in the laboratory to specified concentrations) of the indicator being measured.

Evaluation of Results: The meter should read the expected concentration within defined limits.

Field Duplicates:

A field duplicate is a duplicated stream or lake sample collected and analyzed. They are used to evaluate precision.

Evaluation of Results: The results for two samples should be compared using the relative percent difference between them. The results for three or more samples should be compared using the standard deviation among them. In either case, results are compared with your data quality objectives

Laboratory Duplicates:

A laboratory duplicate is a sample that is split into two or more sub-samples at the laboratory. They are used to evaluate precision.

Evaluation of Results: The results for two samples should be compared using the relative percent difference between them. The results for three or more samples should be compared using the standard deviation among them. In either case, results are compared with your data quality objectives.

Spike Samples:

A sample is split into two sub-samples in the laboratory. One is analyzed according to the specified procedure. The other is "spiked" by adding a known amount of a known concentration of the parameter being measured. It is also analyzed according to the specified procedure. This should increase the concentration in the spiked sample relative to the un-spiked sample by a predictable amount. This is used to evaluate accuracy.

Evaluation of results: The percent of the parameter "recovered" by comparing the spiked to the un-spiked sample is determined. Results are compared with you data

Negative and Positive Plates (for bacteria):

Negative plates: Buffered rinse water (the sterile water used to rinse down the sides of the filter funnel during filtration) is filtered in the same manner as a sample.

Positive plates: Water known to contain bacteria (such as wastewater treatment plant influent) is filtered the same way manner as a sample.

Evaluation of Results: the results for negative planes should be "zero." The results for positive plates should be "too numerous to count" (TNTC).

External Field Duplicates: An external field duplicate is a duplicate lake or stream sample, collected and processed by an independent (e.g. professional) sampler or team. It is used to estimate the accuracy of sampling and laboratory analysis.

Evaluation of Results: The results for two samples should be compared using the relative percent difference between them. Results are compared with your data quality objectives.

Split Samples: A split sample is a sample that is split into two sub-samples at the laboratory or in the field. One sub-sample is analyzed at the project lab and the other is analyzed at the independent lab and the results compared. Where field analyses are required, one sub-sample is analyzed in the field and the results compared. It is used to estimate accuracy.

Evaluation of Results: The results for the two samples should be compared using the relative percents difference between them. Results are compared with your data quality objectives.

Knowns: A quality control laboratory sends samples labeled with the concentration of selected parameters, to the project lab for analysis. Knowns are used to evaluate accuracy.

Evaluation of Results: The results of the sample analysis should be compared with the known concentration using the relative percent difference between them. Results are compared with you data quality objectives.

Unknowns: A quality control laboratory sends samples for selected parameters to the project laboratory for analysis. The concentrations of these samples are unknown to the project laboratory until after it analyzes them. Unknowns are used to evaluate accuracy.

Evaluation of Results: The results of the samples analysis should be compared with the know concentration using the relative percent difference between them. Results are compared with you data quality objectives.

Taxonomic Verification (for Benthic Macroinvertebrates): Benthic macroinvertebrate samples identified by volunteers should be preserved and archived for verification by experienced taxonomist.

Evaluation of Results: The identifications are compared.

Evaluation

Evaluation involves calculating the accuracy and precision of your quality control measures and comparing them to your data quality objectives. In this column, list who and how you will evaluate the quality control samples in terms of whether you met your data quality goals.

The decision to accept or reject data or a portion of it is made after the analysis of all the QC data.

Statistics are used to evaluate QC measures. If you are having an outside source run your QC, you may want to list, "performed by certified lab." If you are doing the evaluation yourself, refer back to Worksheet , which listed your own precision and accuracy data quality objectives

Problem Avoidance and Response Actions

Describe how you will avoid problems and, when they occur, respond to them. See the Background and content section of this step for examples.

Before you can develop a response action, you have to know there is a problem. In Step 11 data validation will be covered from the data management aspect, before and after it is entered into the computer. Your first line of defense is to have a clear set of standard operating procedures for both sampling and analysis. You should develop a consistent way of recording all your measurement, QC results, observations of sampling conditions, instrument calibration, etc. These records will help you track data, identify problems and provide clues to their solution.

Problem avoidance begins at the collection of your first sample. Here are a few ideas of what you can do.

- Double-check the sample bottle label to make sure that you are filling the proper ones.
- Make sure your meter has been properly calibrated, and recheck it at each new site.
- If sampling is done in pairs, one can be the data taker and the other the recorder. The recorder should repeat the recorded information to make sure he/she heard and recorded it correctly.
- Record sampling times, to make sure sample holding times were observed.

- If you are performing measurements in the field, make sure your QC measures meet your requirements before leaving the site. It's easier to redo your measurements at that time.
- Look for results that don't make sense, like a pH of 15, or out of the range of results that you usually encounter at that sampling site.

If you find a problem, define the problem and evaluate the possible causes. What are some of the follow-up investigations actions will you take if you don't meet your data quality objectives or if you find errors or problems in your monitoring? First consider if the problem is sampling or analytical. Once that is decided, some areas to investigate are:

- SOPs are a good place to begin your investigation. Were they followed?
- Equipment maintenance and calibration records. Was the equipment maintained properly? Was if broken?
- Records of historic data provide information on the normal range of values usually encounter at the site.
- Cleanliness. Was equipment and glassware clean?
- Reagents. Have they outdated? Were they stored properly? Were they mixed properly?

Once the problem and cause have been defined, what will you do? It is important to consider your response actions before you need them. It is also important not just to solve the problem, but to also take steps so the problem doesn't arise again. Some possible responses are:

- Troubleshooting will occur to determine the source of error and steps will be taken to remedy the problems.
- If any data doesn't meet project specifications, it may be discarded and re-sampling may occur in order to meet our completeness data quality objective.
- If the problem is sampling error, team members will be retrained.
- If the problem is lack of understanding by team members, they will be retrained and SOPs may be updated.
- If the cause is equipment failure, calibration and maintenance techniques will be reassess and improved.
- Instruments will be calibrated after the problem is resolved.
- Error will be detailed in any projects related reports.
- Data use limitations will be detailed in any project related reports and other documentation as needed.
- Data may need to be flagged and qualified depending upon the nature and extent of the contamination.
- If calibration standard accuracy doesn't meet the specified specifications, the cause of failure will be evaluated.

If the problem originates at the laboratory were you have your samples processed, they will troubleshoot the problem, identify the problem, solve the problem and repeat the analysis. They will also take the necessary steps to ensure that similar problems do not arise in subsequent sampling events. For additional information on problem evaluation, refer to Appendix 7A: Common Internal and External Quality Control Samples and How They Are Evaluated.

Assessment Tables, A tool for making decisions:

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Inventories of Forces of Change: Causes and Sources

Select the indicators based on the monitoring objective and/or question(s) you're trying to answer; select the method based on how you intend to use the data. Keep in mind the limits of your human and financial resources.

Indicator or Tool	Why? Relates to monitoring question you're trying to answer	Methods 	Data Use I 	Data Use II 	Data Use III 	 Time* (hrs) Required	$ Initial Cost**	$ On-going Costs***
Pollution and Alteration Sources A. Point Pollution Sources (e.g. discharges) B. Land-based Non-point Pollution Sources (e.g. urbanization) **C.** Altered Flows (e.g. Dams, water withdrawals, diversions)	To determine the potential sources of pollution and alterations to the aquatic ecosystem and human uses.	○ Research Existing Information	✓	✓	✓	🕓🕓🕓		
		○ Uses, Values, and Threats Survey	✓	✓		🕓🕓		
		○ Windshield Surveys	✓	✓		🕓🕓🕓		
		○ Stream-walks	✓	✓		🕓🕓🕓		
		○ Pipe inventories	✓	✓	✓	🕓🕓🕓		
Rainfall	To see if there is a relationship between rainfall, runoff, pollution, habitat quality, etc.	Gauges	✓	✓		🕓	$	$

Indicator or Tool	Why? Relates to monitoring question you're trying to answer	Methods	Data Use I	 II	 III	Time* (hrs) Required	Initial Cost**	On-going Costs***
Stream Flow	To see if there is a relationship between rainfall, runoff, pollution, habitat quality, etc. To be able to calculate pollution loads.	USGS Method (EPA)	✓	✓		🕓	$k	$
Max. Air Temperature	To establish a relationship between air temperature and water temperature	Direct Measurement or existing NWS data	✓	✓		🕓	$	$

* 🕓🕓🕓: >4hrs; 🕓🕓: ~2hrs; 🕓<1hour. $$$k: 2-4k; $$k: 1-2k; $k: <1K $$$: >100; $$: ~50; $: <25

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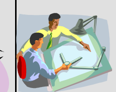
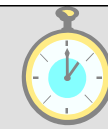
Water Sampling and Analysis

Select the indicators based on the monitoring objective and/or question(s) you're trying to answer; select the method based on how you intend to use the data. Keep in mind the limits of your human and financial resources.

Indicator or Tool	Why? Relates to monitoring question you're trying to answer	Methods 	Data Use I 	Data Use II 	Data Use III 	 Time* (hrs) Required	$ Initial Cost**	$ On-going Costs***
Fecal Indicator Bacteria Present in feces of animals and humans. Indicator of farm run-off (cattle), failing or non-existent septic systems, failing sewage treatment plants, CSO problems.								
***Escherichia coli* and Total Coliforms**	Indicator of sewage contamination and health risk in recreation waters and drinking water (total coliform)	Chromagenic with Easy Gel	✓			🕓 (+ overnight incubation)	$$	$
Fecal Coliforms	Indicator of sewage or animal manure contamination	Membrane Filtration mFC (EPA ???? or equivalent) – used by many states, no longer recommended by EPA	✓	✓		🕓🕓🕓	$$$k	$k
***Escherichia coli* and Fecal Coliforms**	Indicator of sewage contamination and health risk in recreation waters	Membrane Filtration mTEC (EPA 1103.1 or equivalent) – EPA recommended	✓	✓	✓	🕓🕓🕓	$$$k	$k

Indicator or Tool	Why? Relates to monitoring question you're trying to answer	Methods	Data Use I	Data Use II	Data Use III	Time* (hrs) Required	Initial Cost**	On-going Costs***
***Escherichia coli* and Total Coliforms**	Indicator of sewage contamination and health risk in recreation waters and drinking water (total coliform)	Membrane Filtration MI (EPA #600-R-00-013) – EPA recommended, approved for drinking water	✓	✓	✓	🕓🕓🕓 + incubation	$$$k	$$
Enterococcus	Indicator of sewage contamination and health risk in recreation waters	Membrane filtration mE (EPA #1106.1 or equivalent) – EPA recommended	✓	✓	✓	🕓🕓🕓 + incubation		
Escherichia coli	Indicator of sewage contamination and health risk in recreation waters	Colilert with Quantitray	✓	✓	?	🕓 + incubation	$$$k	$$
Biochemical Oxygen Demand	Measures the amount of oxygen used by bacteria to break down organic waste (e.g. sewage). It is a measure of the amount of organic pollution.	BOD 5-day procedure w/Modified Winkler Titration w/syringe or eyedropper (Mitchell/Stapp,)	✓				$	$

Indicator or Tool	Why? Relates to monitoring question you're trying to answer	Methods	Data Use I	Data Use II	Data Use III	Time* (hrs) Required	Initial Cost**	On-going Costs***
Biochemical Oxygen Demand (BOD5)	Measures the amount of oxygen used by bacteria in 5 days to break down organic waste (e.g. sewage). It is a measure of the amount of organic pollution.	BOD 5-day procedure w/Modified Winkler Titration w/syringe or eyedropper (Mitchell/Stapp,)	✓			🕓	$	$
Biochemical Oxygen Demand (BOD5)	Measures the amount of oxygen used by bacteria in 5 days to break down organic waste (e.g. sewage). It is a measure of the amount of organic pollution.	BOD 5-day procedure w/Modified Winkler Titration w/buret or digital titrator	✓	✓	✓	🕓	$	$
Dissolved Oxygen	Measures the amount of oxygen in streams. Essential to understanding the habitat available for most aquatic organisms, including macroinvertebrates and fish.	Modified Winkler Titration w a syringe or eyedropper (Mitchell/Stapp)	✓	✓		🕓	$	$
		Modified Winkler Titration w/buret or digital titrator	✓	✓	✓	🕓	$$	$
Water Temperature	High water temperatures and/or wide fluctuations can stress aquatic life	Direct measurement with thermometer	✓	✓	✓	🕓		

Indicator or Tool	Why? Relates to monitoring question you're trying to answer	Methods	Data Use I	Data Use II	Data Use III	Time* (hrs) Required	Initial Cost**	On-going Costs***
Total Phosphorus	Essential nutrient for plant growth. Often nutrient in shortest supply in fresh waters. Indicator of animal and human wastes (run-off or sewage treatment plants), fertilizer, detergents and disturbed lands where naturally occurring P may be released.	Persulfate digestion followed by ascorbic acid method and color comparator (Mitchell/Stapp)	✓	✓		🕓🕓	$	$
		Persulfate digestion followed by ascorbic acid method and colorimetry (EPA Method 365.2)		✓	✓	🕓🕓🕓	$$$	$
Total Ortho-phosphate	See total P above. Inorganic P, or orthophosphate is the amount actually available for plants to use (which in turn convert it to organic P)	Ascorbic acid methods and color comparator	✓	✓		🕓	$	$
Total dissolved P	Provides insight as to how much of the P entering a stream is from point vs. non-point sources (NPS) Streams with high total phosphorus and low dissolved phosphorus levels usually have most phosphorus input from NPS pollution.	Filtration, followed by persulfate digestion followed by ascorbic acid method and colorimetry (EPA Method 365.2)		✓	✓	🕓🕓🕓	$$$	$

Indicator or Tool	Why? Relates to monitoring question you're trying to answer	Methods	Data Use I	Data Use II	Data Use III	Time* (hrs) Required	Initial Cost**	On-going Costs***
Nitrogen Series □□□**Total Kjeldahl Nitrogen**	The total amount of organic nitrogen. Typically associated with domestic or agricultural contamination.	Digestion followed by Nesslerization + spectrophotometry (SM #4500-Norg B or equivalent)		✓	✓	◷◷◷	$$$	$
□□□**Nitrates**	Form of nitrogen essential to plant growth. Can cause excessive plant growth and O2 depletion. Toxic to humans in drinking water.	Cadmium reduction + spectrophotometry (SM #4500-NO3-E or equivalent)		✓	✓	◷◷◷	$$$	$
		Cadmium reduction + color comparator (Mitchell/Stapp)	✓	✓		◷◷	$	$
□□□**Ammonia (NH3)**	Generated by fish urine, the decay of dead fish and plants. Toxic to fish. Examine in low DO water, where NH3 tends not to be converted to nitrate.	Distillation followed by Nesslerization + spectrophotometry (SM #4500NH3 C or equivalent)		✓	✓	◷◷◷	$$$	$

Indicator or Tool	Why? Relates to monitoring question you're trying to answer	Methods	Data Use I	Data Use II	Data Use III	Time* (hrs) Required	Initial Cost**	On-going Costs***
Temperature	Habitat. Critical for aquatic life. Each organism has tolerance range. Relates to amount of O2 that can be dissolved in water.	Direct measurement with thermometer, thermocouple or thermister	✓	✓	✓	🕓	$	$
Conductivity	Indicator of potential pollutants that conduct. Presence of electrolytes such as salt. Metals, chloride, phosphate, nitrates raise. Oil and organic matter lower.	Direct measurement with a meter (EPA Volunteer Methods Manual)	✓	✓	✓	🕓	$$	$
pH	Indicates degree of acidity of water. Habitat. Organisms have a tolerance range. Indicator of acid mine drainage, acid deposition from burning of fossil fuels, acid discharges.	Sample collected and measured with a pH meter, pocket meter or litmus paper	✓	✓	✓	🕓	$	$
		Direct measurement with pH meter with probe suitable for low ionic strength waters (EPA Method 150.1)		✓	✓	🕓	$$	$

Indicator or Tool	Why? Relates to monitoring question you're trying to answer	Methods	Data Use			Time* (hrs) Required	Initial Cost**	On-going Costs***
			I	II	III			
Total Alkalinity	Measure of capacity of water to neutralize acids. Presence of limestone (a source of calcium carbonate) and other rocks/minerals that provide alkaline buffers.	Single end point sulfuric acid titration w/ bromcresol green/methyl red using dropper bottle (ALLARM)	✓	✓				
		Double end point sulfuric acid titration w/ digital titrator and pH meter (RN Manual)		✓	✓			
Acidity	The base neutralizing capacity of water is known as acidity.	Titration with measured amount standard acid to pH of 4.0, EPA#305.1		✓	✓			
		Phenolphthalein Indicator followed by tritration with sodium hydroxide (Delaware Riverkeeper Network)	✓					

Indicator or Tool	Why? Relates to monitoring question you're trying to answer	Methods	Data Use I	Data Use II	Data Use III	Time* (hrs) Required	Initial Cost**	On-going Costs***
Hardness	The hardness of a water is a measure of the concentration of positively charged particles in the water, but primarily it is equivalent to the calcium and magnesium concentration of the water.	Computed from results of calcium and magnesium or titrated (SM #3500Ca, EPA 130..2 or equivalent)		✓	✓			
Iron	The most important trace element for plants. Iron above 0.3 mg/L is objectionable in water because of staining of laundry and plumbing fixtures	*Sampling:* 500 mL pre-cleaned plastic bottle, iced to 4C *Analysis:* Inductively Coupled Plasma Atomic Emission Spectrometric Method, EPA #200.7		✓	✓			
		Treatment with FerroVer Iron Reagent followed by color comparator (Delaware Riverkeeper Network)	✓	✓				

Indicator or Tool	Why? Relates to monitoring question you're trying to answer	Methods	Data Use			Time* (hrs) Required	Initial Cost**	On-going Costs***
			I	II	III			
Total Suspended Solids	The weight of suspended matter in water after filtering. Indicator of sedimentation.	Gravimetric method, dried at 103-105□C. (SM#2540D or equivalent)		✓	✓			
		Filtration of sample through glass fiber filter + drying & weighing – based on SM #2540D (Delaware Riverkeeper Network)	✓	✓				
Total Dissolved Solids	The concentration of dissolved organic and inorganic chemicals. Dissolved solids may include calcium, magnesium, sodium, potassium, bicarbonate, sulfate, chloride and silica. High total dissolved solids may effect the aesthetic quality of the water	Gravimetric method, filtrate dried at 1800C. (SM#2540C or equivalent)		✓	✓			

Indicator or Tool	Why? Relates to monitoring question you're trying to answer	Methods	Data Use			Time* (hrs) Required	Initial Cost**	On-going Costs***
			I	II	III			
Manganese	Primarily regulated because of aesthetic problems associated with elevated levels, Elevated levels can disrupt the nervous system and regeneration of hemoglobin.	*Sampling:* 500 mL pre-cleaned plastic bottle, iced to 4☐C *Analysis:* Inductively Coupled Plasma Atomic Emission Spectrometric Method, EPA #200.7		✓	✓			
Turbidity	Measure of cloudiness or opaqueness of water. Influenced by the amount and nature of suspended organic and inorganic material. The source could be fine sand, silt, and clay (i.e., soil separates); organic material, particles of iron and manganese or other metal oxides, rust from corroding piping, or carbonate precipitates.	Sample collected and measured with a nephelometer (RWN adaptation of Standard Methods #2130)	✓	✓	✓			

Indicator or Tool	Why? Relates to monitoring question you're trying to answer	Methods	Data Use			Time* (hrs) Required	Initial Cost**	On-going Costs***
			I	II	III			
Sulfate	Widely distributed in natural waters, but is typically less than a few mg/L. Higher levels may be from acid mine drainage	1) Turbidimetric: Sulfate ion converted to a suspension. The resulting turbidity is determined by a nephelometer, and compared to a curve prepared from standard sulfate solutions, EPA#375.4 2) Colorimetric, Automated, Methylthymol Blue, using an Autoanalyzer II, EPA #375.2Standard Methods		✓	✓			
Total Residual Chlorine	Chlorine remaining in water after treatment.	*Sampling*: Consult with biologist for sampling method. This is tricky due to TRC's dissipation and flow patterns. *Analysis*: Amperometric Titration Method, SM#4500ClD.		✓	✓			

Biological Sampling and Analysis

Select the indicators based on the monitoring objective and/or question(s) you're trying to answer; select the method based on how you intend to use the data. Keep in mind the limits of your human and financial resources.

Indicator or Tool	Why? Relates to monitoring question you're trying to answer	Methods	Data Use			Time* (hrs) Required	Initial Cost**	On-going Costs***
			I	II	III			
Benthic Macro-invertebrates - Intensive	Direct assessment of aquatic life reflects health of aquatic ecosystem. Robust indicator Reflect conditions over time	***Intensive***: **Collection:** Quantitative or semi-quantitative field collection of 3 composite replicate samples w/ net, Surber, or artificial substrate in wadeable waters, **Subsampling:** 100 and 1/4 sample or entire sample. **Identification** Families **Assessment:** Based on comparison to reference site or biocriteria EPA RBP-based		✓	✓	🕓🕓🕓	$$k	$$

Wadeable Waters

Indicator or Tool	Why? Relates to monitoring question you're trying to answer	Methods	Data Use I	Data Use II	Data Use III	Time* (hrs) Required	Initial Cost**	On-going Costs* **
Benthic Macro-invertebrates - Moderate	Direct assessment of aquatic life reflects health of aquatic ecosystem. Robust indicator Reflect conditions over time	***Moderate***: **Collection:** Semi-quantitative field collection of 3 replicate samples w/ net in wadeable waters, **Subsampling:** 100 and 1/4 sample or entire sample. **Identification** Major groups **Assessment:** Based on internal guidelines	✓	✓		🕓🕓	$k	$
Benthic Macro-invertebrates - Basic	Direct assessment of aquatic life reflects health of aquatic ecosystem. Robust indicator Reflect conditions over time	***Streamside***: Field collection and identification of major groups, assessment based on relative abundance and estimated richness (EPA, RWNRN)	✓			🕓	$k	$

* 🕓🕓🕓: >4hrs; 🕓🕓: ~2hrs; 🕓<1hour. $$$k: 2-4k; $$k: 1-2k; $k: <1K $$$: >100; $$: ~50; $: <25

Physical Habitat Sampling and Analysis

Select the indicators based on the monitoring objective and/or question(s) you're trying to answer; select the method based on how you intend to use the data. Keep in mind the limits of your human and financial resources.

Indicator or Tool	Why? Relates to monitoring question you're trying to answer	Methods	Data Use I	Data Use II	Data Use III	Time* (hrs) Required	Initial Cost**	On-going Costs***
Habitat Walk	Sometimes you can learn more from visual inspection that monitoring. Note adjacent banks and land use.	Visual Assessment of various habitat characteristics (EPA and others)	✓	✓		🕓🕓		
Benthic Macro-invertebrate Habitat Assessment	Habitat quality is a key factor in determining the biota that lives in the water body.	Field observation and rating of key habitat characteristic relative to reference condition (RWN Benthic Macroinvertebrate Monitoring Manual or EPA Volunteer Stream methods Manual – muddy bottom Assessment adaptation of EPA RBP II or equivalent)	✓	✓		🕓🕓		

Indicator or Tool	Why? Relates to monitoring question you're trying to answer	Methods	Data Use			Time* (hrs) Required	Initial Cost**	On-going Costs***
Stream Channel Measurements Embeddedness	A measure of sedimentation that can reduce attachment surfaces for invertebrates.	Estimated for four particles at each of cross sections at site (EPA EMAP Protocol or equivalent)	✓	✓		🕒🕒🕒		
Stream Channel Measurements Channel Cross-sections	Reveals deposition al areas and how they change over time.	Measure elevations at intervals across stream ("Stream Channel Reference Sites" USFS or equivalent)		✓				
Stream Channel Measurements Longitudinal Profile	Reveals deposition al areas and how they change over time.	Elevations of channel bottom and water surface ("Stream Channel Reference Sites" USFS or equivalent)		✓				
Stream Channel Measurements Bottom Composition	A more quantitative measure of bottom composition, which is a key habitat feature for benthic dwellers.	Pebble Count: Collection and measurement of at least 100 stream bottom particles at 10 cross sections to determine distribution among various size classes. ("Stream Channel Reference Sites" USFS or equivalent)	✓	✓				

Case Study 1

Case Study 2

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U.S. EPA, On-line Training Courses on Water Quality Assurance and Quality Control Activities, http://www.epa.gov/quality/trcourse.html, including:

Assessing Quality Systems

Detecting improper Laboratory Practices

Introduction to Data Quality Assessment

Introduction to Data Quality Indicators

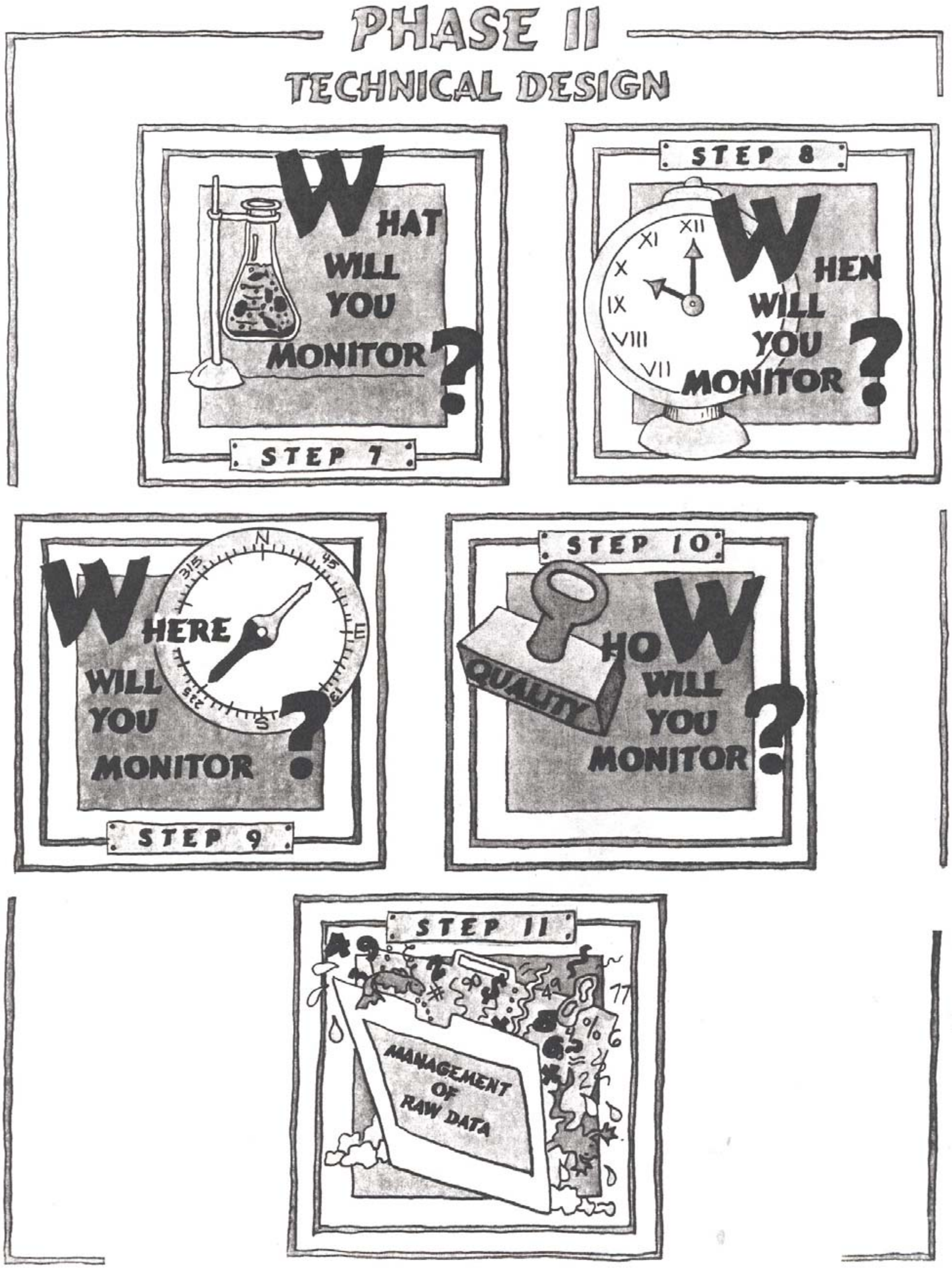
Introduction to Data Quality Objectives

Introduction to Quality Assurance Project Plans

Introduction to Quality Management Plans

Note to pilot participants: This is not a complete list - share your sources with us!

Resources


PHASE II
TECHNICAL DESIGN
WHAT WILL YOU MONITOR?
STEP 7
STEP 8
WHEN WILL YOU MONITOR?
WHERE WILL YOU MONITOR?
STEP 9
STEP 10
QUALITY
HOW WILL YOU MONITOR?
STEP 11
MANAGEMENT OF RAW DATA

Step 11: Management of Raw Data: (Data Management Plan Part 1)

"The problems we face today are too great to be met w/out active engagement. Solutions require the ingenuity of those most affected, creativity the emerges from diverse perspectives, commitment by those that have a stake, it takes an active citizenry to create public decision making that is accountable to address today's crises."

Frances Moore Lappe

About This Step – *This step is designed to accomplish 5 things:*

1. Inventory of Data Management Needs or identify what data, results and information is being generated that needs to be managed, including laboratory, meta-data and quality assurance and control data.
2. Identification of the minimum data elements (information) required, desired or preferred by you and targeted decision makers.
3. Description and illustration of data management processes that move data through the data management system.
4. Identification of data management system support elements and tools that allow for consistent, reliable and comparable data management (design and relationships, hardware, software, GIS and web considerations, naming conventions, data thorns, user considerations, safety/archive and training).
5. Mechanism to document data management of raw data/results and associated support elements, *Data Management Plan Part 1*.

Why Do This Step?

How will data transform into information?

Regardless of whether you are starting from scratch and only are planning to collect data or have small to large amounts of data already managed to some degree, take the time to plan, evaluate and document your data management system.

Data and results generated by monitoring activities are numbers but are not necessarily information. Data and results are transformed into information through analyses, summaries, interpretation, findings, conclusions and recommendations we develop. That develops a story, we have a story to take into action decisions. The act of reporting the information, or story, to our targeted data users is the minimum "action" we conduct as part of a holistic monitoring design. We call this data utilization, turning results into information and delivering to a decision maker or endpoint. We also may take other action with the information such as, modifying a BMP or developing a watershed plan. Monitoring results are always just results.

The ability to manage data or results is an essential element in the process of turning results into information and delivering that information to a decision maker. Phase 3 products, a Data management Phase 1 and Phase 2 Plan, are design to help you build a foundation that will support the transformation of your results into information, all the processes that enable that to happen.

I understand data management is necessary but really why is a plan necessary?

If you plan to manage your data you provide an opportunity to involve and integrate more people into your monitoring and assessment program or information program. Most monitoring programs, maybe every one, began to manage data when it started to be generated as opposed to having a plan for how to manage data before data were ever collected. Sometimes this works just fine. More often however, data management and lack of planning takes more time from us than it saves us in high speed function. Take this simple example:

> You are monitoring 10 stations, once a month for 10 variables. Doesn't sound like much data, but look further. That equates to 100 pieces of data per month and 1,200 data points and data sheets per year (more if you have > one data sheet per sample event). Now add that you have been doing this for 10 years that is 12,000 data points. This does not include any quality assurance or control data, meta-data or information about the data, methods or purpose. Data generated can add up in volume very quickly. Would you want to walk into 12,000 data sheets, even well organized, and start to electronically manage that data? Oh, and a report is due next week to renew that monitoring funding.

Typically without forethought and planning we manage the data "as it rolls in or a report is needed" and thus end up with a foundationless add-on data management system. We add on what we need as we go. Apply this approach to building a house. We need a room so we build it, then we need another so we attach it, we need a third and attach it and so on. There is no foundation underneath the entire house. It may function and provide shelter, but if we could build it from scratch it would be structurally sound and provide longer term shelter and perhaps less care to take care of. Certainly with technology changing there is a certain degree of this inherent to the work.

You may ask who cares how we get there as long as we get there? Some value can be given that statement. The fruit of the discussion lies in the question, "is our data management system providing the tools to manage the data efficiently and effectively for us to turn monitoring results into information, a story, and get the information to my data users for a decision and how do I know this?" If you answer yes and can further describe how, then celebrate and focus on other aspects of your monitoring design. If you cannot, the most likely you are expended resources that could be used elsewhere.

We are suggestion two data management plans. The first *Data Management Plan Part 1,* Phase 2 Step *11*, designs how to manage the raw data, results and information being generated. Items you know you are generating from Phase 1 and 2 results. We break this into two areas, first inventory and design of what results need to be managed and second data management system support decisions. The second *Data Management Plan Part 2*, Phase 3 Step 15, designs what you know today about how those data will transform into information and be delivered. Analyses, interpretation, formulating recommendations and reporting are all iterative processes that will evolve. We are asking you to plan how you think you will start.

Where are we in the Big Picture Illustration?

Phase 1	Step 1: Share Watershed Vision and Desired Outcomes (Results) Step 2: Scope Inventory (Physical, People and Information) Step 3: Identify Monitoring Reason(s) and Data Use(s) (Assessment Type) Step 4: Develop Monitoring Questions (Refinement of Monitoring Reason) Step 5: Target Decision Makers and Info Needs (Refinement of Data Use) Step 6: Summarize with Information Blue Print-Data Pathway Fact Sheet)
Phase 2	Step 7: What Will You Monitor? Step 8: When Will You Monitor? Step 9: Where Will You Monitor? Step 10: How Will You Monitor to Meet Data Quality Objectives? **Step 11: Management of Raw Data (Data Management Plan Part 1)**
Phase 3	Step 12: Data Summary and Analysis Step 13: Interpretation, Conclusions and Recommendations Step 14: Communicating and Delivery Step 15: Management to Generate Info (Data Management Plan Part 2)
Phase 4	Step 16: Who Will Do What? Task Identification Step 17: Evaluation of Effectiveness (of Plan and Implementation) Step 18: Documentation and Communication (of M & A Plan)

Products (see Figure Phase 2 Product List):

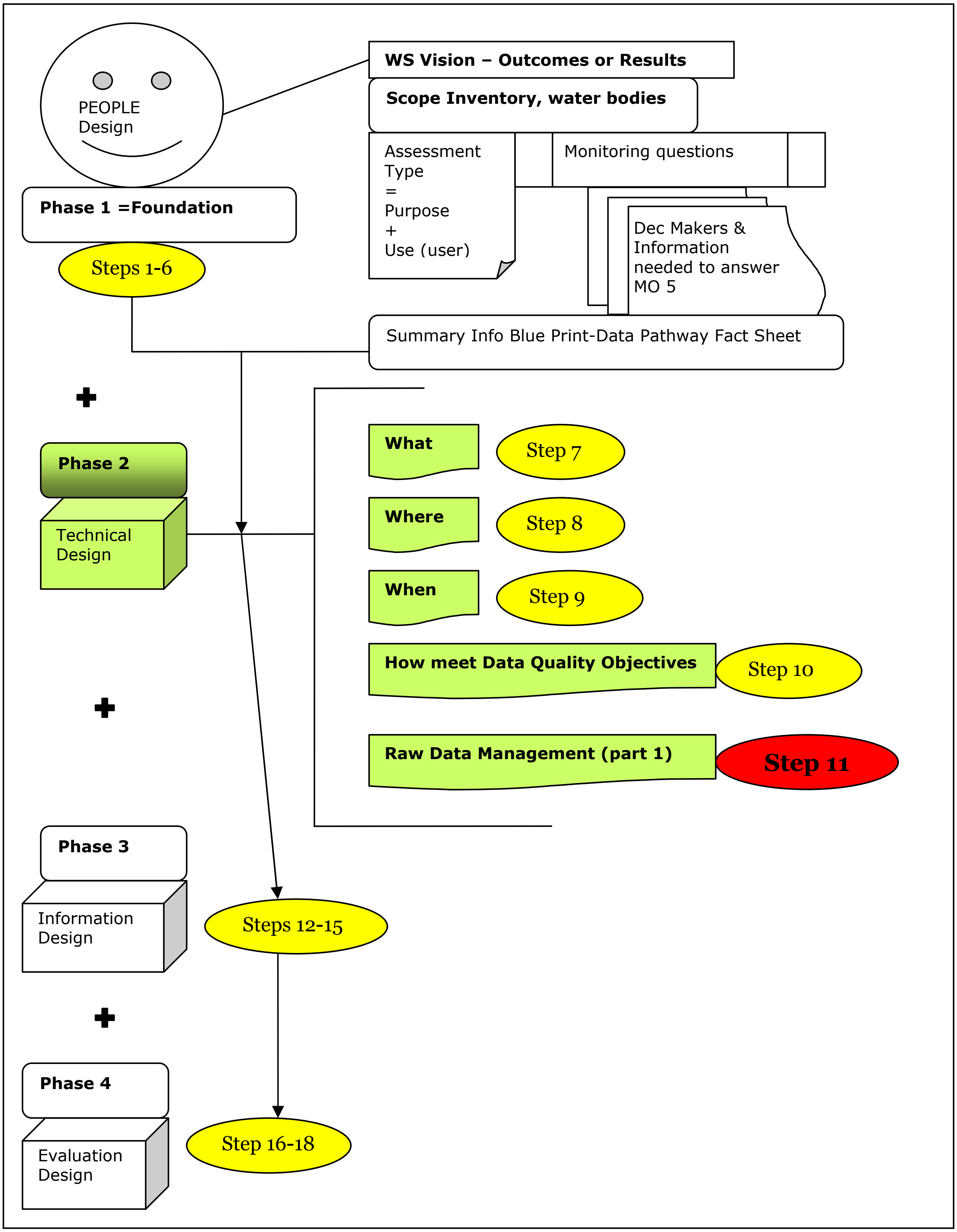
Part A. Inventory and design of what to manage and how will integrate:

- ✓ A list of specific results data collection/monitoring will be generating and how each aspect will be handled from recording, entry, validation, storage, retrieval and transfer
- ✓ A list of meta-data (information about the data/results, including quality assurance and control data) that you or targeted decision makers need to support decision
- ✓ Identified minimum data elements or information you or decision maker needs, requires or prefer.
- ✓ Data management process that move data through the data management system—more after Steps 13-16 in this Phase 3.

Part B. Data Management System Support Decisions:

- ✓ Database Design and relationships
- ✓ Hardware and software inventory, status and needs, including graphics, GIS and Web interface needs and plan
- ✓ Identified and documented naming and numbering conventions, miscellaneous thorns (detection limit, etc.), user considerations, process tools, safety measures, archive protocols, and training plan
- ✓ *Documented Data Management Plan Part 1, A and B*

Phase 2 Product Illustration:



What Should Be Done Before This Step

The results from Phase 1 or the people orientation provides the foundation for Phase 2 Steps. Thus, ideally you need to have identified a watershed vision and desired outcomes with associated assumptions and external factors. Defined combination of monitoring purposes and uses, we call Assessment types. For each assessment type a list of monitoring questions the data is to answer and how that question will be answered. For each monitoring question, a list of targeted decision makers, their decision, how they make that decision and what information they need to make the decision. A format to document and summarize the results, we have suggested the information blueprint.

The results from Phase 2 Steps, provide the foundation for Phase 3 Steps, Step *11* being the first, data management. Thus, ideally you have identified the components of how you will collect data, what variables and information you will collect, when, where, how and how good the data needs to be (quality assurance and control measures). This also includes field and laboratory analyses. These specifics need to be identified and documented in order to understand what data needs managing for findings, analyses, interpretation, reporting/utilization and making decisions, recommendations or taking action.

Basic Tasks

Basic Tasks are numbered to correlate with the overall 1-18 Steps provided in these guidance modules followed by the basic task sequence step to complete. For example Step 4, basic task 2 would be numbered as Basic Task Step 4.2, Step 3.3 correlates to Step 3, Basic Task 3.

11.1 Identify who will make the decisions about this step and who should be involved in the planning process (they may be different).

11.2 Self Assessment: Identify what decisions have been made and their effectiveness.

PART A. INVENTORY AND DESIGN OF WHAT TO MANAGE AND HOW WILL INTEGRATE:

11.3 Inventory of data you will be generating for each monitoring question, document all possible results and then and how each data element will be:

- Recorded in the field and/or lab and how
- Entered electronically or electronically transferred
- Validated for accuracy, precision and entry, both field and laboratory and the interface between

Data elements are the individual data generated, chemical, biological, physical, indicators, numeric or narrative.

11.4 Inventory and document the meta-data you or decision maker need to accompany the raw data or information you will generate and deliver. Meta-data is information about the raw data or results, including station location information, units, methods, qualifiers, quality assurance and control measurements and actions, etc.

11.5 Decide and document the minimum data elements you or decision makers need, prefer or require.

11.6 Draw a diagram of how information will flow from creation to storage, illustrating all the "activities" or "transformations" the data will undertake to be ready to turn into information and delivered (Phase 3). This illustrates the connections between field/lab, meta-data and results, quality assurance and control data and results, other validation and data, etc.

11.7 Put this together in meaningful way to be Part 1 of your Data Management Plan Part 1, for your monitoring information system. Use the provided outline, edit or develop your own. Gaps and needs can be identified and placed in the Action Plan, last Basic Task.

PART B. DATA MANAGEMENT SYSTEM SUPPORT DECISIONS

11.8 Inventory and document hardware and software will employ and why for data validation and storage (ready for data-to-information functions). Determine your database structure and relationship hierarchy.

11.9 Inventory and document naming and numbering conventions.

11.10 Inventory and document your miscellaneous thorns (missing data points, detection limits, zero values, range results, narrative results such as "too numerous to count" etc.) and plan to address.

11.11 Inventory and document relevant System User considerations. Answer the series of questions and document the results.

11.12 Inventory and document relevant Process tools and protocols.

11.13 Determine and document data safety plan for hard and electronic data, back-up and archive protocols, and data management system training and/or cross training plans, make a table of duties/process and those who will/should know them.

11.14 Add Part B results to the *Data Management Plan Part 1* for completion. See provided outline, edit or develop your own for these items.

11.15 Update *Inventory Master List* and *Plan.*

11.16 Update *Information Blueprint – Data Pathway Fact Sheet* for each monitoring question.

11.17 Place Products in your *Watershed Monitoring and Assessment Plan*.

11.18 Place your identified gaps and needs regarding this step in the *Action Plan* (what you need to plan to complete this step and or overall monitoring and assessment plan).

Worksheets

Work sheets are listed below. Not all Basic Tasks have an associated work sheet. To simplify completion of products for each step, the worksheets or broken into small subsets of tasks. This requires moving the results of one task into the next task and will seem redundant, especially if completing worksheets by hand. Worksheets are provided in word here for ease of reproducibility. These are a starting point, we encourage you to customize these and reproduced them in an electronic format, in Excel for example, where it is easy to move information from one area to another by cutting and pasting.

Work Sheets are numbered to correlate with Basic Steps and the overall Steps in these guidance modules. Each consecutive work sheet is lettered a, b, c and so forth, preceded by the Basic Task sequence step, preceded by the Step number. For example, Worksheet Step 4.2.a and Step 4.2.b, correlates to Step 4, Basic Task 2, Worksheet a and Worksheet b. In theory worksheet a needs to be completed before worksheet b.

Worksheet 11.2.a **Self Assessment Step 11 Worksheet and Products to be completed Prior to this Step, Part 1 and Part 2**

PART A – INVENTORY OF RAW DATA

Worksheet 11.3.a **Inventory of data you will be generating for each monitoring question, document all possible results and then and how each data element will be:**

- Recorded in the field and/or lab and how
- Entered electronically or electronically transferred
- Validated for accuracy, precision and entry, both field and laboratory and the interface

Worksheet 11.4.a **Inventory and document the meta-data you or decision maker need to accompany the raw data or information you will generate and deliver**

Worksheet 11.5.a **Decide and document the minimum data elements you or decision makers need, prefer or require**

Worksheet 11.6.a **Draw a diagram of how information will flow from creation to storage, illustrating all the "activities" or "transformations" the data will undertake to be ready to turn into information and delivered (Phase 3). This illustrates the connections between field/lab, meta-data and results, quality assurance and control data and results, other validation and data, etc.**

Worksheet 11.7.a **Put this together in meaningful way to be Part 1 of your** *Data Management Plan Part 1*, **for your monitoring information system. Use the provided outline, edit or develop your own. Gaps and needs can be identified and placed in the** *Action Plan*, **last Basic Task.**

PART B – SYSTEM SUPPORT DECISIONS FOR ENTRY, STORAGE AND RETRIEVAL FOR OTHER FUNCTIONS

Worksheet 11.8.a **Inventory and document hardware and software will employ and why for data validation and storage (ready for data-to-information functions).**

Worksheet 11.9.a **Inventory and document naming and numbering conventions.**

Worksheet 11.10.a **Inventory and document your miscellaneous thorns (missing data points, detection limits, zero values, range results, narrative results such as "too numerous to count" etc.) and plan to address.**

Worksheet 11.11.a **Inventory and document relevant System User considerations. Answer the series of questions and document the results.**

Worksheet 11.12.a **Inventory and document relevant Process tools and protocols.**

Worksheet 11.13.a **Determine and document data safety plan for hard and electronic data, back-up and archive protocols, and data management system training and/or cross training plans, make a table of duties/process and those who will/should know them.**

Worksheet 11.14.a **Add Part B results to the** *Data Management Plan Part 1* **for completion. See provided outline, edit or develop your own for these items.**

Worksheet 11.17.a **Place Products in your** *Watershed Monitoring and Assessment Plan.*

Worksheet 11.18.a **Place your identified gaps and needs regarding this step in the** *Action Plan* **(what you need to plan to complete this step and or overall monitoring and assessment plan).**

How to do Worksheets

For Sheet 11.2.a Self Assessment Step 11 Worksheet and Products to be completed Prior to this Step, Part 1

Part 1. Complete the self assessment section of the worksheet to evaluate what you have or what decisions have already been made. This will help you focus on what you need from this step and incorporate valuable existing information or products into this plan.

Part 2. Next, to prepare to complete this step the following, you need to have the following items addressed:

- ✓ Desired set of outcomes or results that the monitoring and assessment activities will be designed to help achieve
- ✓ Identified monitoring and assessment activities, specific combinations of a monitoring reason plus an associated data use; we call this an Assessment Type. You may have multiple Assessment Types.
- ✓ For each Assessment Type, the list of specific monitoring questions the monitoring and assessment will be designed to answer.
- ✓ For each monitoring question, the targeted decision makers, the type of decisions they will make and the information they need to make them (as specific as possible).
- ✓ A minimal scoping inventory that identifies the watershed boundary and water bodies you are focusing on (rivers, lakes or wetlands), physical attributes of water bodies (including status, uses, etc.), relevant cultural or historical aspects, existing data sets or monitoring efforts and others in the watershed who either you want to influence or could help you implement.
- ✓ Technical sample plan including what monitor (indicators, benchmarks, criteria, etc.), where and when monitor, how will meet data quality objectives (methods, how good does the data need to be for decision makers, quality assurance and control measures), and how will manage and verify raw data/information.

This is the ideal list, if you do not have any of these, they become a gap or need that should be addressed before any data is collected or analyzed, even if the answers aren't perfect or you don't have a large degree of confidence surrounding them, they should be attempted as the starting point. This is what you are evaluating in this step-your monitoring and assessment plan.

Worksheet 11.2.a Self Assessment Step 11 Worksheet and Products to be completed Prior to this Step, Part 1.

Part 1 Self Assessment of Known Evaluation Products and Processes

1. **Determine if you "have" or "don't have" the item, mark the appropriate box. If you don't have it and determine you don't need it, explain why in the comments document. You may not need to know but perhaps your target decision makers, board or membership might want to know.**

2. **If you have the item "documented", mark that box. If so, list in the comments where, hard copy, chapter in a document, electronic file name and location, etc. The assumption is you value the ultimate goal to document and communicate your M & A plan, activities and results.**

3. **If you have the item, assess the use of it, use the scale below or provide your own answer and comments.**

   Rating Scale for USE:
   0=doesn't exist so use is nil
   1=don't know why would need or understand item
   2=exists, don't know where it is, if it is used, etc. so use is essentially nil
   3=exists and use some of time
   4=exists and use all the time
   5=wish it existed, would use it lots

4. **If you have the item, assess the effectiveness of it, just because something exists or is used does not mean it is effective in its use, use the effectiveness scale below or provide your own answer and comments.**

   Rating Scale for EFFECTIVENESS, assumes material exists:
   0=not effective or functional at all
   1=incomplete (all elements are not there) and some existing parts need revising
   2=incomplete but what is there is okay
   3=complete (all elements are there), some parts okay but need revising
   4=complete and effective

Item	Have	Don't Have	DOC	Assessment of Use (Scale 0-5)	Assessment of Value / Effectiveness (Scale 0-4)	Comments
33. . Data management of field datasheets, standardized, validated, stored, retrievable						
34. Data management for electronic data (entry, validation, stored, retrievable)						
35. Data management for meta-data, data about the results (location, who collected, etc.)						
36. Identification of meta-data and minimum data elements						

37. Data management from laboratory data (electronic, validated, stored, retrievable)						
38. Data backup, archive, data management training plan						
39. Data management for field/lab qa/qc information						
40. Standardization (naming convention, numbering convention, recording below detection, narrative results, etc.)						
OTHER?						

*DOC=Documentation, *M & A= Monitoring and Assessment

5. To make this assessment useful, determine what your gaps and needs are regarding this step in order to focus your effort in completing this step.

Worksheet 11.2.a Self Assessment Step 11 Worksheet and Products to be completed Prior to this Step, Part 2.

Part 2 Products to be completed before this step, in order to complete this step

Item	Response
Desired set of outcomes or results that the monitoring and assessment activities will be designed to help achieve:	
Assessment Types, specific combination of one monitoring reason and data use(r):	
For each Assessment Type, the list of specific monitoring questions:	
For each monitoring question, the targeted decision makers, the type of decisions they will make and the information they need to make them (as specific as possible):	
Watershed(s) and Water bodies of focus:	
Physical attributes of Water bodies (status, use, etc.)	
Existing Data or monitoring efforts:	
Indicators, benchmarks and criteria list:	
List of monitoring locations/rationale:	
List of monitoring frequencies:	
Methods list, list of data quality objectives (methods, how good does the data need to be for decision makers), quality assurance and control measures)	

PART A – INVENTORY OF RAW DATA

For Sheet 11.3.a **Inventory of data you will be generating for each monitoring question, document all possible results and then and how each data element will be.**

Data elements are the individual data generated, chemical, biological, and physical, indicators, numeric or narrative. From Phase 2, Step 7, list all the indicators and possible results. Goal is to list and characterize what you are generating such that if you took it to a data management guru (even if that is you), you can see the span of what you need to accommodate in "electronic language".

Tips:

1. *Include every "result" you will generate.*
2. *Define the typical "value" for each result. Include meaningful information such as:*

   Units

   Possible range expect, if appropriate

   Significant digits and decimal points

   If numeric (number only), character (anything other than a number) or a combination
3. *Define how result is "generated" by a staff person recording it, from an instrument reading, analytical lab process with hand written results or electronic results, etc., how do you get it?. In the example below we have three categories to choose from (hand, electronic and website)*
4. *Define where the result is "recorded", if by hand list specific data sheet, if electronic name the file, type and whose computer it is on, if it is a photo or other type label it.*
5. *Determine if the way you receive the result is validated and ready to go or needs more data validation, such as validation of data entry, validation against quality assurance measures or control samples, validation against another data set, etc. In your* **Data Management Plan** *you can describe what validation needs to occur.*
6. *Determine the final resting place or "storage" for this data for which it will be retrieved for data-to-information functions. a*
7. *This characterization will also help you provide consistency and a better product in data recording across samplers, data managers, reporting, etc.*
8. *Make several tables, edit the columns, produce something to characterize your data management needs for your 'data' manager, staff turnover and to make data management support decisions that will actually facilitate this piece.*

EXAMPLE Worksheet 11.3.a

Indicator	Typical Result	Unit /Other	N or C	How Rec	Where Rec	Validated?	Final Resting Place
Temp	XX.Y	Degree Celsius	N	Hand	Field DS	Y	Access Chem Table
DO concentration	XX.Y	Mg/L	N	Hand	Field DS	Y	Access Chem Table
DO Sat	XXX	%	N	Hand	Field DS	Y	Access Chem Table
Zinc Diss	XXX.Y	Ug/L	N	Elec	Access DB	Y	Access Chem Table
Zinc Total	XXXX.Y	Ug/L	N	Elec	Access DB	Y	Access Chem Table
Copper Diss	XXX.Y	Ug/L	N	Elec	Access DB	Y	Access Chem Table
Copper Total	XXX.Y	Ug/L	N	Elec	Access DB	Y	Access Chem Table
Ammonia	XX.YY	Mg/L	N	Elec	Access DB	Y	Access Chem Table
Total Sus Solids	XXX.Y	Mg/L	N	Hand	TSS Excel SS	Y	Access Chem Table
Macro Species List	Family, genus, Species	Name, XXX found	C and N	Elec	Excel SS	N	Access Bug Table
Bug Kick Sketch	Scanned drawing	NA	NA	Hand	Field DS	N	Linked File to Bug Table of JPG's
Wet Width	XXX.Y	Feet	N	Hand	Field DS	Y	Access Phys Hab Table
Subst Comp	Descriptio on, XXX	%	N and C	Hand	Field DS	Y	Access Phys Hab Table
Discharge	XX,XXX.YY	CFS	N	Website	Elect	N	Access Phys Hab Table
Site Photo	Scanned photo/digi tal	NA	NA	Hand	Photo	N	Linked File to Bug Table of JPG's

Worksheet 11.3.a Inventory of data you will be generating for each monitoring question.

From Phase 2, Step 7, list all the indicators and possible results. Include the typical value (include significant digit/decimals), unit (if appropriate, how recorded, where generated, validation, final resting place). Make several tables, edit columns, characterize what you are collecting so it can be assessed in "data management" language.

Indicator	Typical Result	Unit /Other	N *or* C	How Rec	Where Rec	Validation	Final Resting Place

For Sheet 11.4.a **Inventory and document the meta-data you or decision maker need to accompany the raw data or information you will generate and deliver. Meta-data is information about the raw data or results, including station location information, units, methods, qualifiers, quality assurance and control measurements and actions, etc.**

Step 1. Inventory what generating

In the example below we have provided a way to subset the meta-data by categories, project, organization, station and results. This may or may not be meaningful for you. The task is to identify and characterize the "information" about the results that either you our your target decision makers need to make their decision. ***Step 11 Resource Guide*** provides a menu of options to consider.

Meta-data is important to track, validate and determine how it will "travel" through your information system to end up with results to be delivered. You don't want the end result to be your decision maker won't accept your data/results because you didn't include station location information for example. So, plan ahead.

Step 2. Determine and document the source (so it can be educated to your needs)

Just like you track the source of monitoring results you need to track the source of your meta data. It may be a one time effort, like looking up a method, or an ongoing effort such as tracking the names and addresses of volunteer sample collectors. If you can identify the source and track it, then you have more control over how you receive the information.

Step 3. Describe how it is managed, where live and key relationships

For each piece of meta-data, determine how you will manage it, where live and what relationship it has to the results. This is extremely important from an "electronic data" language perspective. This is the beginning of identifying the relationships between results and meta-data that a data manager needs to produce final products that keep the integrity of data and meta-data and allow for example, the station name to "show up" with a selected set of results.

Use the information generated in the previous Phase 1 and 2 Steps. For indicators Step 7, for Data Quality Objectives Step 10, etc.

As with every other step in this workbook, the degree of effort should equate with the need. If you are collecting a small set of data a few times, then a data management plan is overkill. However, if you collect a small set of data, every month for 10 years, for 10 indicators, that becomes a large database that requires some degree of management to be useful.

EXAMPLE Worksheet 11.4.a

Meta-data Item	Source	How Manage, Where live and relationship to results
Indicator units	Sample Design	With result, live in chemical table, necessary to describe result
Indicator narratives	Sample Design	Such as substrate composition, condition of riparian habitat, treat as 'results' and keep in respective tables
Field Methods	Sample Operating Procedures Manual, State Health Dept SOP	Update when method is changed, keep in table with list of methods, EPA test ID number, can request in one of our meta data reports
Lab Methods	Sample Operating Procedures Manual, State Health Dept SOP	Update when method is changed, keep in table with list of methods, EPA test ID number, can request in one of our meta data reports
Station location information	Staff generate	Must have this info to process sample, have an access table with descriptor fields, standardize entry, can search results by station request
Result qualifiers	Volunteer and staff generated	Field in appropriate databases, chemistry, biological, physical for field and lab to include any information that might help with interpretation, can be selected as part of result reporting
Field quality assurance / control results **(could list specific items)**	Field and lab	Actual results available by sample identification for field blanks, duplicates and unknowns. Kept in an access table linked to results. Laboratory "actions" summarized in annual report, text format versus every control result
Project Id	Staff generates	Keep a table with project information, linked to entities involved, helps report data for project reporting to lump results
Organization Id	Staff generates	Give each organization and id number, so data can be reported for each organization, have a table with organization name, address, update ongoing, some quality assurance data is by organization not sample event
Volunteer Id	Staff generates	Give each volunteer and id number, data can be reported for each organization, have a table with organization name, address, update ongoing

Worksheet 11.4.a Inventory and document the meta-data you or decision maker need to accompany the raw data or information you will generate and deliver.

Step 1. Inventory what generating, Step 2. Determine and document the source (so it can be educated to your needs) and Step 3. Describe how it is managed, where live and key relationship.

Meta-data Item	Source	How Manage, Where live and relationship to results

For Sheet 11.5.a **Decide and document the minimum data elements you or decision makers need, prefer or require.**

Minimum data elements are equivalent to the minimum data elements/results and meta-data that you and your decision makers need to make decisions. Look at Worksheet 11.3.a and 11.4.a and what you know about you and your targeted decision makers information needs and cut/paste or make of list of what your minimum data elements will be. ***Step 11 Resource Guide*** *provides a menu of options to consider as well. The Background and Content Section provide more examples and rationale.*

It is helpful to think of the secondary and further categories as "fields" in a database or information you might want in a report, records to keep. Add a third and fourth tier if useful. Adapt and edit to serve your needs.

The purple dashed line means, etc. or keep listing items under this category and make another tier or category if needed.

EXAMPLE Worksheet 11.5.a

You can use this list to make sure you have a "table" or place to store this information, a mechanism to obtain it, get it into your databases, validate it and update it.

Primary Category	2nd Category	3rd Category	Explanation
Contact	Sources of Data		This element identifies the primary sources or providers of data to the system, whether within or outside the agency, including: name, address, telephone number including area code and e-mail address of the agency to direct questions about the sample analytical results.
		Org Name	The legal, formal name of an organization that is the primary source of data.
		Mailing Address	The exact address where a mail piece is intended to be delivered, including urban-style street address, rural route, and PO Box.
		Mailing City	The name of the city, town, or village where the mail is delivered.
	Sample Person	Sampling Entity/Person Formal	The legal, formal name of an organization that is the sampling entity
		Mailing Address	The legal, formal name of an organization that is the sampling entity.
	Laboratory /Field	Laboratory Formal Name	The formal title of the laboratory facility.
		Mailing Address	
Results	Value Unit		The name of the determinate quantity for a standard of measurement used for measuring dimension, capacity, or amount of something (e.g., g/L, pCi/L, CFU/mL, etc.).
	Analyte Name		The name assigned to a substance or feature that describes it in terms of its molecular composition, taxonomic nomenclature or other characteristic.
Sample Reason	Sample Type		Assessment Type, trend, storm event, permit compliance, use your choice list
	Start Date		The calendar date when collection of the analyte was started, reported as 4-digit year, 2-digit month, and 2-digit day in YYYYMMDD format.

	End Date		The calendar date when collection of the analyte was finished, reported as 4-digit year, 2-digit month, and 2-digit day in YYYYMMDD format.
Location	Water body Name		Name of the lake, stream, river, estuary, aquifer, reach name in the National Hydrography Dataset or other water feature related to the physical site.
	Station ID		The name or number that uniquely identifies the sample station.
Collection	Type		Routine sample, field blank, control, lab duplicate, etc.
	Media		Water column, sediment, macroinvertebrate, etc.
Preservation	Container		Free text: Sample container type
	Filtered		
Analysis	Method Number		The method number of the analytical method used, represented as a reference number:
	date		The calendar date when analysis of the analyte was finished, reported as 4-digit year, 2-digit month, and 2-digit day in YYYYMMDD format.
	Detection limit		The name of the determinate quantity for a standard of measurement used for measuring dimension, capacity, or amount of something (e.g., g/L, pCi/L, CFU/mL, etc.).
	Run Batch		A lab-defined identifier for a batch of analyses done on one instrument that make up a sequence of analyses during which the instrument is continuously in control.

Worksheet 11.5.a Decide and document the minimum data elements you or decision makers need, prefer or require

Primary Category	2nd Category	3rd Category	Explanation

For Sheet 11.6.a **Draw a diagram of how information will flow from creation to storage, illustrating all the "activities" or "transformations" the data will undertake to be ready to turn into information and delivered (Phase 3). This illustrates the connections between field/lab, meta-data and results, quality assurance and control data and results, other validation and data, etc.**

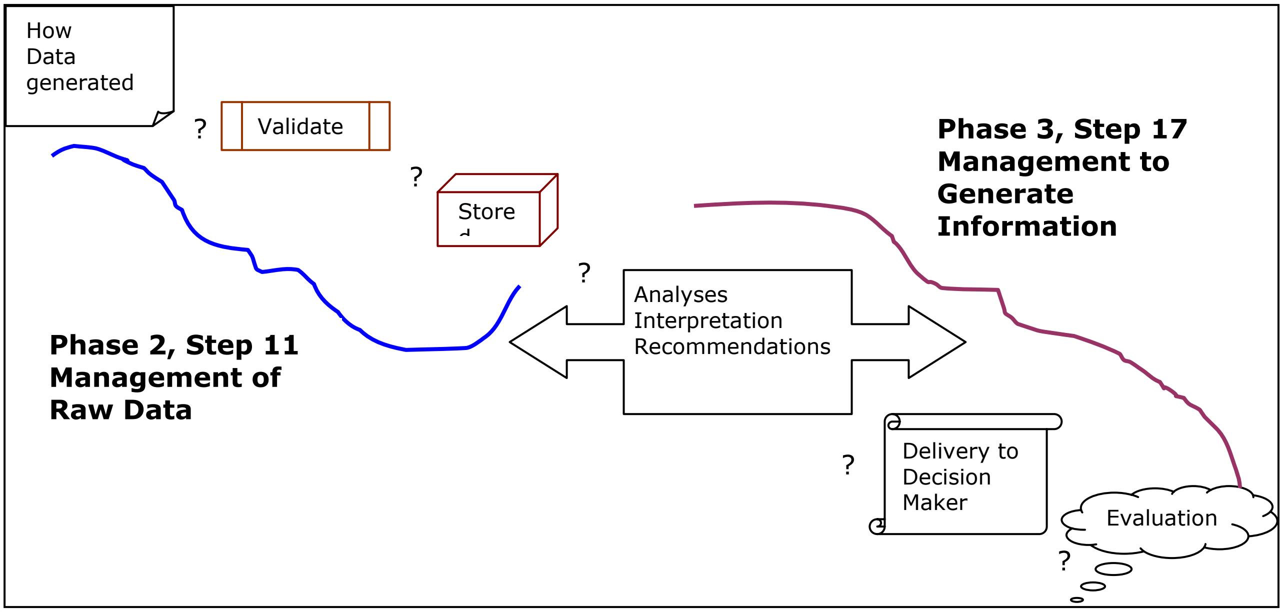
Illustrations help others understand the big picture and can help others help you design effective database management.

Below is an example from a Program in Colorado that uses citizens, students and teachers to collect data in conjunction with staff. They collect water chemistry, macroinvertebrates and physical habitat data. The volunteers do field tests and send samples to a lab. Refer to the key bottom right for the symbolization. The donut holes show where the data will be retrieved and "end" up in the data-to-information process. After the donut is the multi-page icon, indicating the data-to-information processes that lie ahead. Data tables are the clipped cornered box, the round oval shape are unique identifiers that connect one table to the tables below it, such as kit_number uniquely identifies every organization. The double pane, clipped icon illustrate data entry type pages that show where each piece of data is "entered" into the system. Sample Tracking, for example, is a table that every sample processed is first entered into the system.

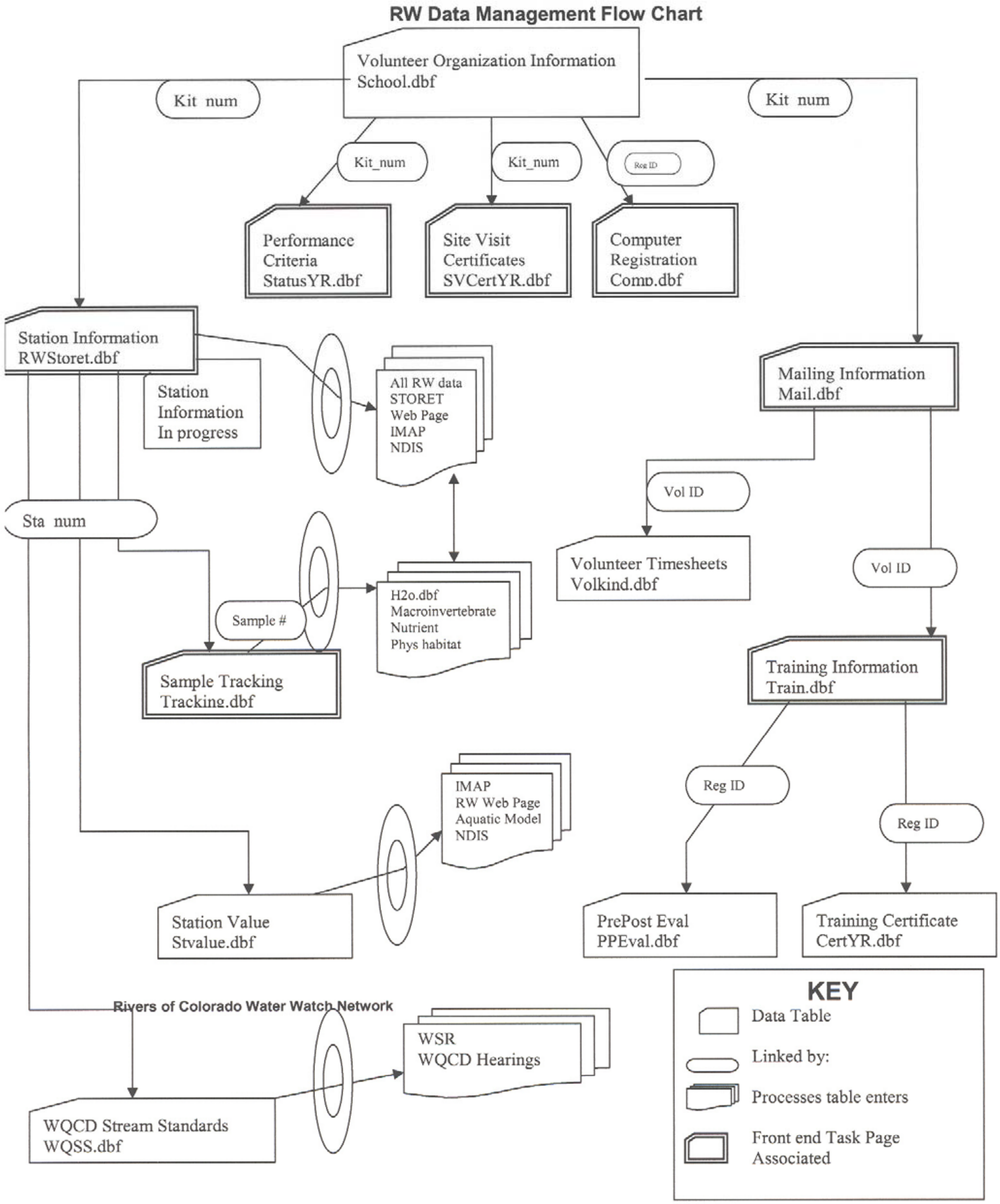
This example illustrates how meta-data, such as school, station, trainees and sample id, date and time are all related and their hierarchy. In this system you can't have a station unless it is associated with an organization.

In this example there is only one program generating the data through the use of many organizations, but the data generated is the same. Another example might be multiple data sources, formats, and methods and that means different transfer, validation and conversion processes, but it could be diagramed. Your program maybe very simple, but it is still valuable to document and illustrate how the data is managed.

Your data management plan can contain all the table names, function and field names. Do what is necessary and meaningful.



Example of Colorado River Watch (RW) Data Management Flow Chart:


RW Data Management Flow Chart
Volunteer Organization Information
School.dbf
Kit num
Kit num
Kit_num
Kit_num
Performance
Criteria
StatusYR.dbf
Site Visit
Certificates
SVCertYR.dbf
Computer
Registration
Comp.dbf
Station Information
RWStoret.dbf
Station
Information
In progress
All RW data
STORET
Web Page
IMAP
NDIS
Mailing Information
Mail.dbf
Vol ID
Sta num
Volunteer Timesheets
Volkind.dbf
Vol ID
Sample #
H2o.dbf
Macroinvertebrate
Nutrient
Phys habitat
Sample Tracking
Tracking.dbf
Training Information
Train.dbf
IMAP
RW Web Page
Aquatic Model
NDIS
Reg ID
Reg ID
Station Value
Stvalue.dbf
PrePost Eval
PPEval.dbf
Training Certificate
CertYR.dbf
KEY
Data Table
Linked by:
Processes table enters
Front end Task Page
Associated
Rivers of Colorado Water Watch Network
WSR
WQCD Hearings
WQCD Stream Standards
WQSS.dbf

Worksheet 11.6.a **Draw a diagram of how information will flow from creation to storage, illustrating all the "activities" or "transformations" the data will undertake to be ready to turn into information and delivered (Phase 3). This illustrates the connections between field/lab, meta-data and results, quality assurance and control data and results, other validation and data, etc.**

For Sheet 11.7.a **Put this together in meaningful way to be Part 1 of your** *Data Management Plan Part 1*, **for your monitoring information system. Use the provided outline, edit or develop your own.**

The Plan should provide a characterization of what collecting and the processes and functions needed to get the 'data' verified, validated, in the final storage place ready to retrieve for the data-to-information functions. Result and Meta-data characterization was completed in Worksheets 11.3.a, 11.4.a and 11.5.a. Refer to the Background and Content Section to understand outline items.

Data Management Plan, Part 1 Possible Outline **1 (more by source)**: **Part A**

- I Data Source
  - A Master List of what generating
    - 1 Results (Worksheet 11.3.a)
    - 2 Meta-Data (Worksheet 11.3.a)
    - 3 Minimum Data Elements Summary (Worksheet 11.3.a)
- II Validation of Results
  - A Field Data (results generated in the field)
    - 1 At Collection by Volunteer
    - 2 Through sample processing
    - 3 Data entry (different levels?)
    - 4 Against Quality Assurance and Control Measures
    - 5 In context with other data
    - 6 Tools used (forms, check lists, etc. Master List)
  - B Laboratory Data (results generated in a lab)
    - 1 Volunteer Lab
      - a Fecal Coliform
        - i Transfer
        - ii Against Quality Assurance and Control Measures
        - iii Tools used (forms, check lists, etc. Master List)
    - 2 Commercial Lab
      - a Metals
        - i Against Quality Assurance and Control Measures
        - ii Tools used (forms, check lists, etc. Master List)
      - b Nutrients
        - i Against Quality Assurance and Control Measures
        - ii Tools used (forms, check lists, etc. Master List)
      - c Macroinvertebrates
        - i Against Quality Assurance and Control Measures
        - ii Tools used (forms, check lists, etc. Master List)
  - C Other Data (drawings, photos, ?)

<u>Data Management Plan, Part 1</u> <u>Possible Outline</u> **<u>2 (more by media type)</u>**<u>:</u> **<u>Part A</u>**

I Data Source

- A Master List of what generating
  - 1 Results (Worksheet 11.3.a)
  - 2 Meta-Data (Worksheet 11.4.a)
  - 3 Minimum Data Elements Summary (11.5.a)

II Validation of Results

- A Field Data (results generated in the field)
  - 1 At Collection by Volunteer
  - 2 Through sample processing
  - 3 Data entry (different levels?)
  - 4 Against Quality Assurance and Control Measures
  - 5 In context with other data
  - 6 Tools used (forms, check lists, etc. Master List)
  - 7 Laboratory Data (results generated in a lab)
- B Laboratory Data
  - 1 Metals
    - (i) Transfer
    - (ii) Against Quality Assurance and Control Measures
    - (iii) Tools used (forms, check lists, etc. Master List)
  - 2 Nutrients
    - (i) Transfer
    - (ii) Against Quality Assurance and Control Measures
    - (iii) Tools used (forms, check lists, etc. Master List)
    - (iv) Macroinvertebrates
- C Other Data (drawings, photos, ?)

Worksheet 11.7.a **Put this together in meaningful way to be *Part A* of your *Data Management Plan Part 1*, for your monitoring information system. Use one of the provided outline examples above, edit or develop your own. Example 2, is provided below:**

I Data Source
- A Master List of what generating
- B Results (Worksheet 11.3.a)
- C Meta-Data (Worksheet 11.4.a)
- D Minimum Data Elements Summary (11.5.a)

II Database Structure and Relationships

III Validation of Results
- A Field Data (results generated in the field)
- B Laboratory Data
  - 1 At Collection by Volunteer
  - 2 Through sample processing
  - 3 Data entry (different levels?)
  - 4 Against Quality Assurance and Control Measures
  - 5 In context with other data
  - 6 Tools used (forms, check lists, etc. Master List)

IV Laboratory Other Data (results generated in a lab)
- A Laboratory Data
  - 1 Metals
    - a Transfer
    - b Against Quality Assurance and Control Measures
    - c Tools used (forms, check lists, etc. Master List)
  - 2 Nutrients
    - a Transfer
    - b Against Quality Assurance and Control Measures
    - c Tools used (forms, check lists, etc. Master List)
  - 3 Macroinvertebrates

V Other Data (drawings, photos, ?)

PART B – SYSTEM SUPPORT DECISIONS FOR ENTRY, STORAGE AND RETRIEVAL FOR OTHER FUNCTIONS

For Sheet 11.8.a **Inventory and document hardware and software will employ and why for data validation and storage (ready for data-to-information functions). Determine database structure (fields) and relationship hierchy in manner that can be documented (illustration, table structure printouts, etc.)**

*Answer the series of questions and determine what you need to ask or employ. See **Step 6 Resource Guide item 1** for data quality objective implications for data management.*

Worksheet 11.8.a **Inventory and document hardware and software will employ and why for data validation and storage (ready for data-to-information functions). Determine database structure (fields) and relationship hierarchy in manner that can be documented (illustration, table structure printouts, etc.)**

Answer the series of questions and determine what you need to ask or employ. See Background and Content for explanations and choices. Add more questions.

Q1A. What hardware do you have now to manage your raw data? Is it meeting your needs? If yes, list the hardware, if not go to 1B.

Q1B. What do you need?

Q2 . What software do you use now to manage your raw data? Is it meeting your needs and if not, why not?

A. Spreadsheet database?

B. Relational Database?

C. Other Needs?

Q3. Do you have your raw data characterized (as Step 11.3.a-11.5.a does), and if so could you take that to a data guru and have them build, tell you what to build, tell you what you need to change, etc.? It may not be so much of you have to do and know it all, but how do you identify what you need in data language?

Q4. Illustrate database structure/fields and relationship hierarchy:

For Sheet 11.9.a **Inventory and document naming and numbering conventions needed by you or targeted decision maker.**

Numbering and naming conventions are "standards" if you will that you employ to provide consistency in the database. The way computers work is that this allows for easy validation and searching of the database if for example, every Station that had the word "Bridge" in it was always abbreviated "Br", with no period. Think of it as a mail carrier sorting mail, if Colorado is always abbreviated CO, then the mail carrier recognizes this easily and their sorting is more accurate more often.

Below is an example of naming conventions from a Colorado Program for Organizations and Stations, the software they used had field size limitations, thus abbreviations where required, but naming conventions do not need to be abbreviations, just consistent ways of recording:

Category	Item	Naming Convention
Organization Name	High School and Middle School	**HS and MS (no periods, case sensitive)**
	Academy	**Acad (no periods, case sensitive)**
	Institution	**Ins (no periods, case sensitive)**
Org Numbering	XXX	**1 to 3 digit unique number, such as 4, 34, or 114**
Station Name	Highway	**Hwy**
	Bridge	**Br**
	County Road	**CR**
Waterbody Name	River	**R**
	Creek	**Cr**
	Gulch	**G**
Waterbody numbering	XXXX	**1 to 4 digit unique number, such as 4, 34, 114, or 3245**
Results	Fecal Coliform	**"TNC" = too numerous to count when positive result**
	Milligram per liter	**mg/l (not capitalized)**

Worksheet 11.9.a Inventory and document naming and numbering conventions.

Complete the following table with relevant numbering and naming conventions. Determine how you will communicate and enforce these as "standards". Edit and modify to meet your needs.

Category	Item	Naming Convention

For Sheet 11.10.a **Inventory and document your miscellaneous thorns (missing data points, detection limits, zero values, range results, narrative results such as "too numerous to count" etc.) and plan to address.**

Identify the various miscellaneous thorns associated with each category of results. See the following example:

Category	Item	Decision
Chemical	No data	Null value, will show up blank in the result table to indicate no data exists for this and if appropriate put comments in qualifier field
	Reporting below detection limit	Choose to report 0, the detection limit value, ½ the detection limit value, or a symbol <detection limit
	Actual 0 values	Record as zero
	Range adequate for all results	Determine significant reporting digit (what method suggests) and make sure field can handle largest and smallest number or large enough to write description if narrative result
	Impossible Results	A value for pH <0 or >14, don't accept, review data source, if cannot find error, leave null
	Rounding	If move data, or report round all results >1 and end in 5 up. All results <1 ending in .1-.9 round down, (or do by indicator)
	Detection Limit really, Practical Quant limit and reporting limit	Determine what getting for each analyte and what needs to be done, nothing, detect to PQL to RL, significant digit adjustment, rounding?
Physical Habitat	Percent substrate composition > or < 100%	**Check data sheet and source, if cannot rectify, null entry**
Macroinvertebrate	Collection occurred, no bugs found	**Place "none present" in field versus null value**

Worksheet 11.10.a Inventory and document your miscellaneous thorns (missing data points, detection limits, zero values, range results, narrative results such as "too numerous to count" etc.) and plan to address.

Identify the various miscellaneous thorns associated with each category of results. See Background and Content for more ideas. Edit to be useful.

Category	Item	Decision

For Sheet 11.11.a **Inventory and document relevant System User considerations. Answer the series of questions and document the results.**

See the following examples. Access implies individual can change something. This level of access can be informal, you request folks not to change or formal in that barriers are built into the software, or a combination.

Q1. How many users do you have and what are their access level needs and functions?

User	Functions	Access Level to what
Volunteer	Field data entry, retrieve all results, some meta-data	C
Contract Staff	Data entry, data validation, some data analysis and reporting	B
Scientist from Organization	Data entry, final validation, oversee all data analysis and reporting	A
Dept Of Health	Result and meta-data retrieval	D
Other Data Users	Result and meta-data retrieval	D

A=access to all data bases

B=can access all databases, but final chemical, physical habitat and biological tables

C= combination access to field database, can change initial (which is not the final), D access rest

D=retrieval access only, cannot change final database

Q2. How many simultaneous users of which part of your system do you have?

Four staff /contractors for primary data tables and for field data entry, need any number of volunteers (140) to be able to enter on webpage at same time if it happens.

Q4. Summarize database management needs and decisions around System User Considerations.

System needs to be able to accommodate multiple users with out loosing data integrity, and needs to have ability to tier access to maintain data integrity.

Worksheet 11.11.a Inventory and document relevant System User considerations.

Answer the series of questions and document the results. See Background and Content Section for further explanations. Modify questions if need to.

Q1. How many users do you have and what are their access level needs and functions?

Q2. How many simultaneous users of which part of your system do you have?

Q3. If you need a tier approach, illustrate it below?

Q4. Summarize database management needs and decisions around System User Considerations.

For Sheet 11.12.a Inventory and document relevant Process tools and protocols.

This will require some thought, but if you understand what you are managing (raw data) and the process it travels through to be validated and ready for retrieval, then you can think of helpful tools and processes This content often gets developed during implementation as needs arise, having a place holder in your plan will allow you to document these items. In the future, staff turnover, etc. individuals will know why some tool or process is in place and keep it updated and/or relevant.

The following is provided for an example:

Tool/Process	Purpose
Chain of Custody	Document no sample tampering but also to verify samples received match data sheets
Data entry log sheet	Tracks the field datasheets that have been electronically entered
Data entry Box on Field datasheet	Tells staff field data sheet has been entered electronically and can be filed
Validation box 1 on Field datasheet	Tells staff field data sheet has been validated for accuracy (correct results)
Validation box 2 on Field datasheet	When checked tells staff field data sheet has been validated for data entry, what is on datasheet is in the electronic database
Validation box 1 in primary result tables	Tells staff field data sheet has been validated for accuracy (correct results) against field quality control samples
Validation box 2 in primary result tables	Tells staff field data sheet has been validated for accuracy (correct results) against lab quality control samples
Final Check Form	A summary table that documents in sample batches the "action" taken from quality control and assurance samples, each batch is 20 samples, of those 20 all passed, or 2 didn't with spikes and were re-run, etc.
Sample issues report for macroinvertebrate samples	This report is reviewed annually and changes to sample protocol, sample preservation or recording are made and documented. These reports on kept on file in XYZ building.

Worksheet 11.12.a Inventory and document relevant Process tools and protocols. Answer the series of questions and document the results.

This will require some thought, but if you understand what you are managing (raw data) and the process it travels through to be validated and ready for retrieval, then you can think of helpful tools and processes This content often gets developed during implementation as needs arise, having a place holder in your plan will allow you to document these items. In the future, staff turnover, etc. individuals will know why some tool or process is in place and keep it updated and/or relevant. Edit as need.

Tool/Process	Purpose

For Sheet 11.13.a **Determine and document data safety plan for hard and electronic data, back-up and archive protocols, and data management system training and/or cross training plans, make a table of duties/process and those who will/should know them.**

This will require some thought, especially if starting from scratch. Have a place holder for it. Excellent tool for staff turnover and communicating to others what doing and what need.

Category	Item	Activity
Data or Results	Field Data sheets	Archived in file boxes, main office warehouse for two years, annually take "old" set, scan in and save in organization electronic file
	Site photos	Scan in or take digital, most current 3 for each station, priority to photos those that follow our photo protocol, keep all of those for log, photos reside in organization file in main office
	Analyzed Samples	Metals kept for two years then recycled. Nutrients kept for one month then recycled. Macroinvertebrates kept indefinitely, check for alcohol content, in main office warehouse B
Electronic	Electronic files to archive annually, archive on Main database machine in specific file under C:/archive	Field metal blank and duplicate values, unknown values, metal laboratory QA samples, nutrient laboratory QA samples, macroinvertebrate QA samples
	Electronic files to update annually, archive on Main database machine in specific file under C:/archive	Organization and Contact database, Organization status, station status, training database, station database, water quality standards database, 303(d) list database, rivercode database, macroinvertebrate taxonomic list and reference collection database
	Primary Data base, meta-data, results, equipment inventory	Primary database and tables, working copy located in Denver machine, Headquarters backs up server daily, copies kept in Durango and Fort Collins updated monthly, on CD biannually
Equipment	Equipment Replacement	If broken or contaminated immediate, pH probes/3 years, sample bottles/5 years, autoburets/10 years, chemicals 1-2/years
Documents	Operating Procedures	Includes sample operating procedures, quality assurance and control plan, training guidance, data management plan, data-to-information plan, sample instruction manual – responsibility matrix identifying for every document/section who is responsible to annually update
Training	Data entry cross training	Scientist and contractor Data Manager 1
	Data Validation cross training	Scientist, contractor Data Manager 1 and Project Manager
	Metals and Nutrient analyses cross training	Scientist, lab technician, contractor lab technician and Project Manager

Worksheet 11.13.a Determine and document data safety plan for hard and electronic data, back-up and archive protocols, and data management system training and/or cross training plans, make a table of duties/process and those who will/should know them.

This will require some thought, especially if starting from scratch. Have a place holder for it. Excellent tool for staff turnover and communicating to others what doing and what need. Edit to serve your needs.

Category	Item	Activity

For Sheet 11.14.a **Develop and add** *Part B* **results to** *Part A*, **Worksheet 11.7.a, the** *Data Management Plan Part 1* **for completion. See provided outline, edit or develop your own for these items.**

Complete what can of Part B *and have place holders for what cannot and put those items in your* Action Plan.

PART A What Managing (from Worksheet 11.7.a, Example Outline 2):

Data Management Plan, Part 1 Possible Outline **2 (more by media type)**: **Part A**

- I Data Source
  - A Master List of what generating
    - 1 Results (Worksheet 11.3.a)
    - 2 Meta-Data (Worksheet 11.4.a)
    - 3 Minimum Data Elements Summary (11.5.a)
- II Validation of Results
  - A Field Data (results generated in the field)
    - 1 At Collection by Volunteer
    - 2 Through sample processing
    - 3 Data entry (different levels?)
    - 4 Against Quality Assurance and Control Measures
    - 5 In context with other data
    - 6 Tools used (forms, check lists, etc. Master List)
    - 7 Laboratory Data (results generated in a lab)
  - B Laboratory Data
    - 1 Metals
      - a Transfer
      - b Against Quality Assurance and Control Measures
      - c Tools used (forms, check lists, etc. Master List)
    - 2 Nutrients
      - a Transfer
      - b Against Quality Assurance and Control Measures
      - c Tools used (forms, check lists, etc. Master List)
      - d Macroinvertebrates
  - C Other Data (drawings, photos, ?)

PART B *System Support Decisions to validate and move data through ready to be "retrieved"*

- I Hardware
  - A What use and why?
- II Software
  - A Spreadsheets, list files, update, responsibility, etc.
  - B Relational Database
  - C Web

- D Other
- III Database Structure and Relationships
- IV Components Design to Assist
  - A Name and Numbering Conventions
  - B Miscellaneous Thorns
  - C User Description
  - D Process Tools and Procedures
- V Safety
  - A Data/Results
  - B Electronic Files
  - C Equipment
  - D Documents
  - E Training

Worksheet 11.14.a Add Part B results to the *Data Management Plan Part 1* for completion. See provided outline, edit or develop your own for these items.

Complete what can of Part B *and have place holders for what cannot and put those items in your* Action Plan*. Edit outline to serve your needs.*

PART B System Support Decisions to validate and move data through ready to be "retrieved"

I Hardware

- A What use and why?

II Software

- A Spreadsheets, list files, update, responsibility, etc.
- B Relational Database
- C Web
- D Other

III Database Structure and Relationships

IV Components Design to Assist

- A Name and Numbering Conventions
- B Miscellaneous Thorns
- C User Description
- D Process Tools and Procedures

V Safety

- A Data/Results
- B Electronic Files
- C Equipment
- D Documents
- E Training

For Sheet 11.17.a Place Products in your *Watershed Monitoring and Assessment Plan*.

Documented Data Management Plan that has:

- A list of specific results data collection/monitoring will be generating and how each aspect will be handled from recording, entry, validation, storage, retrieval and transfer
- A list of meta-data (information about the data/results, including quality assurance and control data) that you or targeted decision makers need to support decision
- Identified minimum data elements or information you or decision maker needs, requires or prefer.
- Data management process that move data through the data management system—more after Steps 12-15 in this Phase 3.
- Database Design and relationships
- Hardware and software inventory, status and needs, including graphics, GIS and Web interface needs and plan
- Identified and documented naming and numbering conventions, miscellaneous thorns (detection limit, etc.), user considerations, process tools, safety measures, archive protocols, and training plan

Worksheet 11.17.a Add products of Step to *Monitoring and Assessment Plan.*

If you completed any Steps this Worksheet is cumulative, use that document. If you have not you complete that aspect that is highlighted for your plan documentation. **Italics mean a sub plan that might be attached or live somewhere else, location of document and contact is what would go in the plan.*

I. People Design, Phase 1
   A. Shared Watershed Vision and Desired Outcomes (Step 1)
      1. Logic Model of Desired Outcomes/Results and activities/target audiences to employ to achieve outcomes
   B. Keepers of the M & A Plan (Step 1)
   C. Watershed Boundary (Step 2)
   D. Water bodies of Interest (Step 2)
   E. Scope Inventory Master List* (Step 2)
      1. Physical Inventory * (Step 2)
      2. People Inventory* (Step 2)
      3. Information Inventory* (Step 2)
         a. Existing Monitoring Efforts (Step 2)

b. Existing Data Sources (Step 2)

4. Inventory Action Plan* (Step 2)

F. Assessment Type(s) List – Monitoring Reason + Use (Step 3)

1. Monitoring Question(s) (Step 4)

2. Targeted Decision Maker(s) (Step 5)

a. Information Needs (Step 5)

3. Information Blue Print – Data Pathway Fact Sheet Per Monitoring Question* (Step 6)

II. Technical Design, Phase 2

A. What (Indicators, Benchmarks, etc.) and why? (Step 7)

B. When and why? (Step 8)

C. Where and why? (Step 9)

D. W(how) will meet data quality objectives? (Step 10)

1. Data quality objectives (Step 5 and 10)

2. Quality Assurance and Control Measures (Quality Assurance and Control Plan)* (Step 10)

E. Data Management for Raw Data (Data Management Plan Part 1)* (Step 11)

III. Information Design, Phase 3

A. Data Summary and Analyses (Step 12)

1. Starting Point (Step 12)

2. Changes (Later)

B. Data Interpretation, Conclusions, Recommendations

1. Starting Point (Step 13)

2. Changes (Later)

C. Communication and Delivery

1. Starting Point (Step 14)

2. Changes (Later)

D. Management Plans to Generate Information (Data Management Plan Part 2)* (Step 15)

IV. Evaluation Design, Phase 4

A. Who Will Do What? (Step 16)

1. Task Identification Matrix (Step 16)
2. Communication Structure and Tools (Step 16)

B. Evaluation Plans (Step 17)

1. Evaluation Plans for M & A Components (Step 17)
2. Evaluation Plans for M & A Implementation (Step 17)
3. Evaluation of inter/intra M & A Activities (Step 17)

C. Documentation and Communication (Step 18)

1. M & A Plan (**this document**, updated Sub documents) (Step 18)
2. Communication and Peer Review Plan (Step 18)
3. Action Plan* (Step 17)

For Sheet 11.18.a **Place your identified gaps and needs regarding this step in the *Action Plan* (what you need to plan to complete this step and or overall monitoring and assessment plan).**

Worksheet 11.18.a **Final *Action Plan* Part 1, Summary:**

If you have completed each Step, or for those you have, you have a cumulated list of gaps and needs related to that Step. Use that same worksheet/document. If you did not complete each Step, look at what each Step is supposed to accomplish and record what your gaps and needs are related to that topic. The goals are to get the gaps and needs in one place to evaluate and prioritize.

Phase 1 Step 1: : (completed in Step 1)
Phase 1 Step 2: : (completed in Step 2)
Phase 1 Step 3: : (completed in Step 3)
Phase 1 Step 4: : (completed in Step 4)
Phase 1 Step 5: : (completed in Step 5)
Phase 1 Step 6: : (completed in Step 6)
Phase 2 Step 7: : (completed in Step 7)
Phase 2 Step 8: : (completed in Step 8)
Phase 2 Step 9: : (completed in Step 9)
Phase 2 Step 10: : (completed in Step 10)
Phase 2 Step 11: Management to Generate Information (*Data Management Plan Part 1***):**
Phase 3 and 4 Steps: Will add Action and Needs as complete each Step and at the end prioritize

Background and Content – Part A

Who should be involved and why?

If you plan your data management you create the opportunity to integrate and involve more people. Managing the data, which really means the system we create to store and retrieve results, transform those results into information and deliver to our data users for our desired decision. Typically this process takes more than one person. Watershed assessment and monitoring design planners, steering committees, technical advisors all should have a vision and plan what will be done with the data in order for the data to have an end point, all before collection begins. Have the end in mind, and a defined data management path that that the data can travel on to on its journey or data pathway from planning to decision to evaluation.

Program coordinators, trainers, volunteers and supporters, sponsors and partners may all have a role in data management. Program coordinators provide leadership for the planning and implementation processes as well as a liaison between those above and those below. Trainers need to emphasize data management is as important as sample collection and sample analyses to answering our monitoring questions. They teach the first phases of validation and data recording. Samplers, volunteer or otherwise need to know why there neat field notes and data recording are important to the monitoring design.

Overview

Data management begins when a data point or value is created, its inception, when something is measured or evaluated. Monitoring and sample analyses generates results. For the Data Management Part 1 Plan, we are focused on planning to manage all the data, results and information we know we will be generating. This includes meta-data, data about the data, quality assurance and control data, methods and procedures and monitoring objectives.

Thus, *Part 1* of the *Data Management Plan* starts from the point of data inception through the necessary steps and processes to prepare it for transformation to information and associated processes. Part A of Plan 1 is to inventory what exactly we need to manage and identify how it needs to be integrated. This includes answering the following questions:

- What data we are generating, field and laboratory inventory. What variables in all media?
- What format (numeric, narrative, units)? How each data are generated (field, laboratory, etc.) and recorded?
- Identify ancillary, meta-data or information about the data that is relevant, such as station location, station identifier, sample event identifier, sample frequency, sample and analytical methods, detection and reporting limit, field and lab QAQC, responsible personnel, etc. that need to travel with that variable?
- Identify the minimum data elements (results and meta-data) that you and your decision maker require and or prefer

- Identify the data management processes for each variable/result, identify and illustrate:
    - How validated
    - How entered electronically and enter validated
    - How stored and retrieved

Part B of Plan one then is to determine the data management system support elements necessary to allow for consistent, reliable and comparable data management and transformation into information. This includes making decisions about:

- Database Design and relationships
- Hardware
- Software
    - databases or spreadsheets
    - graphics
    - statistics
    - mapping and GIS
    - Internet and World Wide Web
- Safety Archiving and backing up
- User Considerations (access, retrieval, multiple users, multiple authority)
- Process tools (forms, logbooks, etc.) that assure and control system
- Naming Conventions
- Data Thorns
- Documentation and Training

Inventory Data You Will Generate or Gather

Let's start by determine what data you need to manage are generating or perhaps using from another source and need to manage it as well. Data from another sources should be reviewed for purpose, methods, quality and adequacy, see Step 2 Resource Guide for a quality check list. If data from another source is already in an electronic format, it might be that some of your data management needs are already decided and met, you can evaluate. If it too is raw data, treat it the same as your raw data.

Raw data is produced by measuring your chosen parameters with the methods, frequency and locations you established in Phase 2, or that others have gathered. This includes numbers generated in the field, in the lab, subjective and narrative data, ratings, descriptions and photos. It includes data for all sample types and sample media. For each indicator you have selected chemical, physical, biological or human, review the type of data that will be generated, including:

- Type of data, numbers, calculated numbers, descriptions, ratings, ranges, drawings, photos, etc.?
- Field or laboratory generated

- Frequency and duration of data generation
- Associated quality assurance and control, field or lab
- Additional indicators to assist with analyses, interpretation and conclusions, for example with dissolved oxygen, if we have temperature and elevation we can determine percent saturation from a milligram per liter concentration
- Information the method requires, such as meter calibration results?

Indicator	Typical Result	Unit /Other	N *or* C	How Rec	Where Rec	Validated?	Final Resting Place
Temp	XX.Y	Degree Celsius	N	Hand	Field DS	Y	Access Chem Table
DO concentration	XX.Y	Mg/L	N	Hand	Field DS	Y	Access Chem Table
DO Sat	XXX	%	N	Hand	Field DS	Y	Access Chem Table
Zinc Diss	XXX.Y	Ug/L	N	Elec	Access DB	Y	Access Chem Table

Where and how is each indicator recorded?

You want to make sure that every piece of data generated is "captured" or recorded and labeled appropriately. Standardizing field data sheets is a good idea for long term record keeping. This includes designing logical, user friendly but comprehensive field data sheets. In addition to recording measured values, the field data sheet might include or incorporate instructions, illustrations and examples of calculation, units, and calibration values, detection limits, precision/accuracy ranges if appropriate. The field data sheet could also include information on everything that was collected or analyzed from this same event, even if not all completed in the field. The field datasheet may need to provide a place for field quality assurance and control results or samples. It also might have spaces for meta-data such as site name, exact location, time, date, sampler's name(s), contact number, weather conditions, comment on a problem or concern with the testing and/or observations, name and model of equipment.

For each indicator, variable or item from above and list how and where it is recorded, in the field or lab, by hand or electronic and how is it tracked or identified, where it is entered/stored if not auto-generated and if lab data how transferred to you? For example:

Field Sampling Data Sheet Information

General For each sample or measurement

- Site location name
- the time each sample or measurement was taken
- Sampling date
- unique ID number for each container
- Monitors' names
- depth of sample or measurement
- Surface water conditions
- type of sample collected
- Additional descriptive comments
- note if a Quality Control Sample
- Water body or watershed
- type of sample container used
- Tidal stage or flow
- site number where sample was taken
- Precipitation within last 12, 24, 48 hrs.
- sample preservation technique (if any)
- General visual observations
- field measurement results
- Current weather conditions

For when the sample is delivered to the lab

- Time the sample arrived at the lab
- Who checked in the samples at the lab

Lab Data Sheet Information

General

- Water body or watershed
- name of lab
- Lab analysis date
- who checked in the samples at the lab
- Computer data entry person
- data proofer
- Additional descriptive comments

For each sample

- Bottle number or sample ID number • site number for each bottle
- Time sample was collected • time sample was received at lab
- Time sample analysis was begun • time sample analysis was finished
- Analysis results (raw) • analysis results (converted to final reporting units)
- Depth or type of sample • quality checks performed
- Who performed the analysis • note if a Quality Control sample
- Quality check results

Identify what ancillary or meta-data you generate or need

Identify ancillary, meta-data or information about the data that is relevant and will help a data user, decision maker or us tell our data story. We call data-about-the-data, meta-data. Types of meta-data to possibly include:

- Contact information
- Data Purposes
- Data Users
- Monitoring Objectives
- Location information
- Time of sample
- Notes during sampling
- Photographs, maps, drawings
- Station, sample event, organization, project identifiers
- Sample Collection methods
- Sample Analysis methods
- Detection and reporting limits
- Data quality objectives (if you have them)
- Field and Laboratory Quality assurance and control information
- Responsible personnel

Meta-data Item	Source	How Manage, Where live and relationship to results
Indicator units	Sample Design	With result, live in chemical table, necessary to describe result
Indicator narratives	Sample Design	Such as substrate composition, condition of riparian habitat, treat as 'results' and keep in respective tables
Field Methods	Sample Operating Procedures Manual, State Health Dept SOP	Update when method is changed, keep in table with list of methods, EPA test ID number, can request in one of our meta data reports
Lab Methods	Sample Operating Procedures Manual, State Health Dept SOP	Update when method is changed, keep in table with list of methods, EPA test ID number, can request in one of our meta data reports
Station location information	Staff generate	Must have this info to process sample, have an access table with descriptor fields, standardize entry, can search results by station request

Laboratory Data

For laboratories in your control, develop standard documentation to record all data generated with each laboratory analyses, including quality assurance and control results and corrective actions taken when quality objectives were exceeded and how they report various data types (below detection limit, zero's, ranges, narrative results such as too numerous to count, etc.). Standardize the manner in which this information is recorded and reported to the appropriate data users.

For laboratories not in your control, ask how they document laboratory procedures. It is assumed at this point you know what detection limits, accuracy and precision you need to meet your data users data quality objectives. Know that your laboratory will meet those needs and how. Ask for to see examples of each analyses data quality objectives, qaqc measures, corrective actions and the like. Know what documentation they need when the sample is delivered, and know how they will deliver results to you (format, when, what other information will be included, etc.).

Regarding electronic transfer of data, you may need to document the transfer with a data receipt or equivalent. This might be necessary to document the delivery of the data for a contract, for your board or simply for the record as documentation of "data delivery" to that data user.

Lab	Analytes	Data generate
1	Al, Cd, Cu, Fe and Zn	Results, field blank and duplicate results, summary of lab blanks, spikes, duplicates, standards performance per batch
2	Total Suspended Solids	Results, nothing else, need to ask
3	Ammonia, Total Phosphorus	Results, summary of lab blanks, spikes, duplicates, standards performance per batch
4	Macroinvertebrate	Taxa list, sample condition report, taxa list updated, reference collection

Identify Minimum Data Elements

Assume you have a data set in front of you that you would like to use. Read the each item in quotes below and think about what your reaction would be and ability to use the data in the quote, if all you were provided is what is in the quote each time:

a. “It was 105.5 ”

b. “Zinc was 105.5 mg/l”

c. “Zinc was 105.5 mg/l, at Johnston Gauge last Wednesday at 10 am”

d. “Zinc was 105.5 mg/l, at Johnston Gauge last Wednesday at 10 am, collected by Samples, Inc. using the health department protocol for collection”

e. “Dissolved Zinc was 105.5 mg/l, at Johnston Gauge last Wednesday at 10 am, collected by Samples, Inc. using the health department protocol for collection, analyzed by atomic absorption EPA method 54.2”

f. “Dissolved Zinc was 105.5 mg/l, at Johnston Gauge, October 23, 2003, at 10 am, from the water column, filtered with a 0.45 micron filter, preserved with nitric acid to pH,2.0, collected by Samples, Inc. using the health department protocol for collection, analyzed by atomic absorption EPA method 54.2, a field blank was also collected”

g. “Dissolved Zinc was 105.5 mg/l, at Johnston Gauge, lat/long 564.9806/-104.38499, October 23, 2003, at 10 am, from the water column, filtered with a 0.45 micron filter, preserved with nitric acid to pH,2.0, collected by Samples, Inc. using the health department protocol for collection, analyzed by atomic absorption EPA method 54.2 with a detection limit of 10 mg/l, a field blank was also collected, a flow was calculated, pH and alkalinity were also collected and analyzed, data is stored at Metro, data was collected for the Cities storm water BMP-1 testing project, contact name is Data B. Jock, 555.678.9012”

Obviously the more information provided the more you know about the result, how it was collected, how analyzed, who collected it, where it lives, what else was done, etc. The more you know about the data the more you can determine if the purpose and quality is sufficient for your use.

This is what we mean by increasing the usability of our date with minimum data elements. The purpose behind a minimum data list is that if everyone collected and or provided a minimum set of information in addition to actual data results, data would be more functional and usable across the board, across multiple users and data purposes, if appropriate of course.

Minimum data elements answer the question, what is the minimum meta-data you need to provide for people who come across your data to understand what you did, where, when, how and why? Minimum data elements are the minimum indicators, variables and meta-data that we, our organization and/or our decision maker require, prefer or desire. If you completed the Information Blueprint, Step 6 or Step5 identifying the information needs of your decision maker, this is an easy step. It is difficult if your decision maker has not or cannot identify these. Then you need to conduct research, ask credible individuals and make the best possible decision for the plan at this time.
This is important to identify and document in order for others to be able to reproduce your work, compare their work to yours, and or not duplicate unnecessarily. It also provides credibility to what you are doing and not doing, minimizes data misuse or misrepresentation. By developing and committing to a minimum data requirement list , you are stating that, "these meta-data elements (list) are required to accompany the data in some form, through analyses, interpretation, conclusion and reporting as necessary, to maintain monitoring design integrity".

EXAMPLE

The National Water Quality Monitoring Council developed a recommended minimum data list, please see **Step 11 Resource Guide**. The EPA STOrage and RETrival (STORET) data base has a less rigorous minimum data elements. The Colorado Water Quality Monitoring Council modified the National Water Quality Monitoring Councils minimum data element list for Colorado.

Also see the Basic Task Worksheet Example

Many of your states have minimum data requirements for 303(d) listing and delisting or data used in triennial review to modify criteria, designated uses or stream classifications. This type of minimum data requirements may include items such as:

- data must be no older than five years
- must exceed 3 out of 5 variables (such as temperature, pH, cadmium, nitrate and selenium for example, if 3 of these 5 criteria are exceeded then…)
- data must be collected by a certified technician
- data must be received by…

If your targeted decision maker has minimum data requirements you need to know what they are so that your data can be used by the decision maker. If your decision maker does not have minimum data requirements, you can customize the concept of minimum data elements for your work. You might want to address all the topic areas with the depth and breadth that is appropriate, contact information, results, reason for sampling, date and time, location information, sample collection information and sample analyses information. The concept is valid for organizing data that 100 years from now, someone could utilize because all the data about the data (meta data) is included with the results.

Identify and determine your starting point regarding minimum data elements.

Identify the data management process to move data

The concept is to identify how data is moving from one step to the other, what goes, what stays, how does it travel, who makes it travel, etc. You can discover overlap and identify efficiencies, missing links, etc. What tools, electronic and non-electronic are used to move data through initiation to storage, for validation, evaluation, etc.?

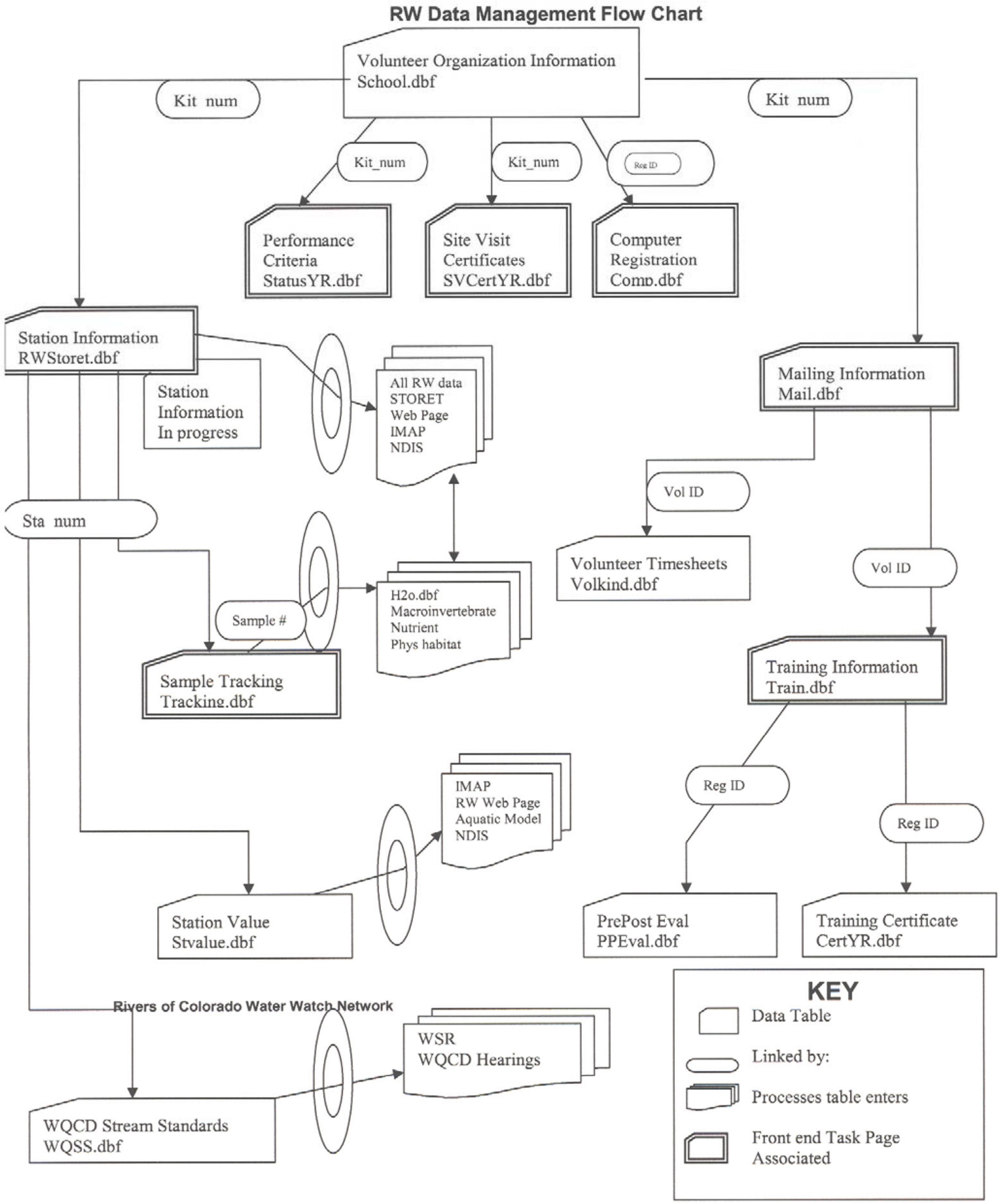
We will look at and diagram how each indicator and meta-data will travel through these processes, look for overlap, efficiencies and needs. You look for Include current tools that are employed to help data move through these processes.

The first item in the process you already identified, how is the result generated or recorded and where. Next is validation.

See Figure for an example from a Program in Colorado that uses citizens, students and teachers to collect data in conjunction with staff. They collect water chemistry, macroinvertebrates and physical habitat data. The volunteers do field tests and send samples to a lab. Refer to the key bottom right for the symbolization. The donut holes show where the data will be retrieved and "end" up in the data-to-information process. After the donut is the multi-page icon, indicating the data-to-information processes that lie ahead. Data tables are the clipped cornered box, the round oval shape are unique identifiers that connect one table to the tables below it, such as kit_number uniquely identifies every organization. The double pane, clipped icon illustrate data entry type pages that show where each piece of data is "entered" into the system. Sample Tracking, for example, is a table that every sample processed is first entered into the system.

This example illustrates how meta-data, such as school, station, trainees and sample id, date and time are all related and their hierarchy. In this system you can't have a station unless it is associated with an organization.

In this example there is only one program generating the data through the use of many organizations, but the data generated is the same. Another example might be multiple data sources, formats, and methods and that means different transfer, validation and conversion processes, but it could be diagramed. Your program maybe very simple, but it is still valuable to document and illustrate how the data is managed.


RW Data Management Flow Chart
Volunteer Organization Information
School.dbf
Kit num
Kit num
Kit_num
Kit_num
Reg ID
Performance
Criteria
StatusYR.dbf
Site Visit
Certificates
SVCertYR.dbf
Computer
Registration
Comp.dbf
Station Information
RWStoret.dbf
Station
Information
In progress
All RW data
STORET
Web Page
IMAP
NDIS
Mailing Information
Mail.dbf
Sta num
Vol ID
Volunteer Timesheets
Volkind.dbf
Vol ID
H2o.dbf
Macroinvertebrate
Nutrient
Phys habitat
Sample #
Sample Tracking
Tracking.dbf
Training Information
Train.dbf
IMAP
RW Web Page
Aquatic Model
NDIS
Reg ID
Reg ID
Station Value
Stvalue.dbf
PrePost Eval
PPEval.dbf
Training Certificate
CertYR.dbf
Rivers of Colorado Water Watch Network
WSR
WQCD Hearings
WQCD Stream Standards
WQSS.dbf
KEY
Data Table
Linked by:
Processes table enters
Front end Task Page
Associated

Data entry

Whether you, your staff or a laboratory is entering data into an electronic data base, you want a plan to make sure it is entered frequently (reduce time between generation and discovered issues), accurately (what is on the data sheet is what is actually entered) and you have processes to track its entry and validation.

If you plan to manage your data before you start collecting it, you decrease your probability for falling into the "oh my goodness, I have mounds of data to enter, it will never get done" trap. Whenever possible, data entry should occur as close as possible to the time the data was generated. If possible make data enter an actual task, or part of the sample collection event, even if only some of the data can be entered. The less time between collection, entry and validation of that entry the larger the chance to accurately resolve the error.

Human error is one source of error we are responsible for minimizing in order to increase the quality of our results and information. Any human entered data needs to be checked and validated for entry errors. This is different than validating data for accuracy and precision. It is simple checking to see if the number on paper matches the number entered electronically. Always keep a hard copy of the data or originals, if you loose the electronic you have the hard, but you need the hard copy to validate the data entry.

Employ the use of templates. Templates can help with data entry standardization and with data manipulations. The theory behind templates is that they are "blank" electronic forms. You call them up, like pulling a blank form from the file cabinet, fill it out, do your calculating or graphing move the graphs or calculations to a third. The template is never saved with the data in it. It may not be possible for one software to handle all your needs efficiently. Perhaps, a template stores the data, you import to another to do calculations and/or graphing and a third for reporting. This may be helpful if your calculation template requires a lot of disk space before data is even imported to it.

EXAMPLE

How are results validated and when?

For each indicator, variable or item from above and list how it is the result itself validated for precision and accuracy and if it is entered for accuracy? For example:

EXAMPLE

There is no right or wrong way to conduct validation. No validation is unacceptable, even for the most rigorous program. Validation starts with where the result is generated, in the field or lab, by the technician asking, 'is this result seem reasonable?", and if not exploring reasons why. You will identify numerous validation steps along the data management process to ensure data integrity when the result is delivered to the decision maker as a story. Some of those process points include:

- at generation
- between each and every transfer (field to laboratory, laboratory to storage, field to storage, storage to data manipulation, etc.), watching for translation errors, unit consistency,

rounding and replacement errors. Sometime this involves sample transfer and sometimes it is just the data, see RESOURCE.

- format changes or result transfer from one format/location to another, data entry from hard form to electronic
- evaluate result against relevant quality control and assurance data
- if combining data sets
- edits of database and tables

EXAMPLE

How stored and retrieved

You want to consider where the storage of the data will be, ready for the transformation to information. Typically, once data is validated and ready, it is stored some where and taken from that storage to another place for manipulation, graphing, analyses, interpretation and reporting. This helps ensure that those data processes will not alter the original data base or its integrity. Where is the final resting place for each result and meta-data item? Add this to your table.

How will what individuals obtain access and retrieve the data for various purposes. This should be planned so that the tools employed will serve the primary users. Developing tiered access approaches are common. An example might be the data manager has access to all data and change anything. Project managers have access to all data and meta-data , Public, etc…

Background and Content – Part B

Part B of Plan one then is to determine the data management system support elements necessary to allow for consistent, reliable and comparable data management and transformation into information. This includes making decisions about:

- Database Design and relationships
- Hardware
- Software
  - Relational databases or spreadsheets
  - Data-to-information needs (Phase 3, Step 17) such as graphics, statistics, mapping and GIS, Internet and World Wide Web
- Naming Conventions
- Data Thorns
- User Considerations (access, retrieval, multiple users, multiple authority)
- Process tools (forms, logbooks, etc.) that assure and control system
- Safety, Archiving, Backing up and Cross Training

Database design and relationship considerations

What are we talking about when we say database design? Database design provides direction for managing data just as a construction blueprint provides the foundation and direction for building a structure. A blueprint illustrates what will be built, with what material and to what dimensions for a builder to follow, how the pieces will fit together in steps/processes to make a building. Inherently the blue print illustrates the relationship and timing between structural and material components such as the foundation, the walls, the ceiling, plumbing, electricity and finish work.

Similarly, a database design illustrates how an individual data point is handled from generation to endpoint (all processes and steps in between) for information ready for decision maker to make decision. The construction blue print is the foundation for the tools and processes selected to build the structure. Similarly the database design is the foundation to identify the tools, such as hardware and software, and processes to support moving a data result through the system. Data base design identifies the relationship and timing between the plan, tools and processes.

Building blueprint (what, how and relationships)	database design
Material used to build	data/results generated
Tools used to build	hardware, software, support processes
Project manager, contractors	Project Manager, database manager, folks analyzing, etc.
Owner of structure	Decision makers

An example of an identify relationship hierarchy could be:

1. Project / Meta-data (Id # if multiple)

    1.1 Organization / Meta-data (Id # if multiple, can you have >1 organization / project?)

    1.2 Individual with organization / Meta-data (Id # if multiple, can you have >1 individual / organization?)

        1.1.1 Station location / Meta-data (Id # if multiple, can you have >1 station / organization?)

            1.1.1.1 Sample Event identifier (identifier for sampling event, regardless of what was collected/analyzed that event)

                1.1.1.1.1 Chemical results per station

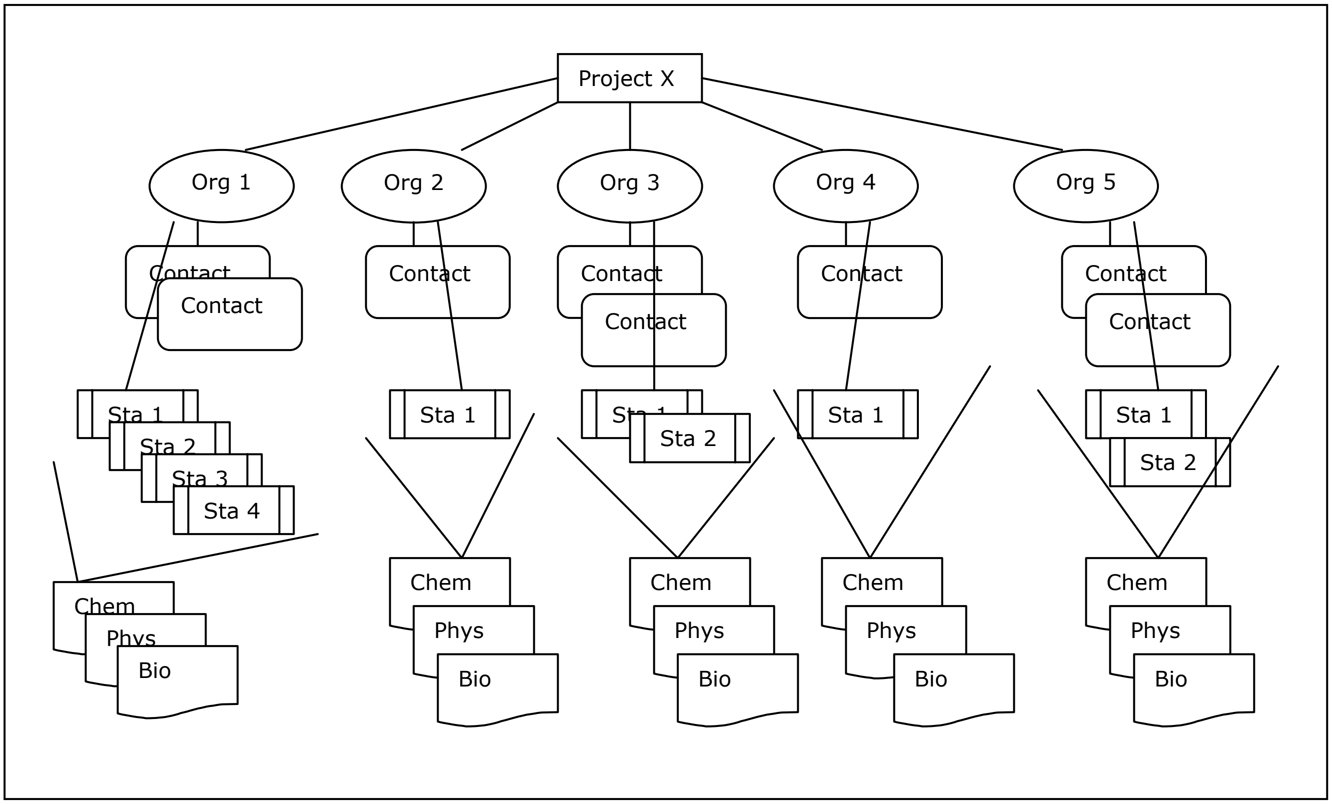
                    Field
                    Lab
                    QA/QC
                    Meta

                1.1.1.1.2 Physical habitat results per station
                    Field
                    Lab
                    QA/QC
                    Meta

                1.1.1.1.3 Biological results per station
                    Field
                    Lab
                    QA/QC
                    Meta

In this example, the data is organized by project, then organization, then by individuals, then by station, then by results. One project can have many organizations. Organization can have many individuals. Combination of organization / individuals can have many stations. Any one station can have many sampling events and each sampling event can have many types of results. This illustrates the one-to-one and one-to-many relationships of the database design and what type of data integrity you need to maintain. This example says, "for every result, a sampling event, a station, organization/individual contact and project id must be identified". In this example, the defined relationships and data integrity states that without the meta-data described above, a particular data point or result has no meaning, and thus cannot be "entered" and "moved" through the data management system.

Viewed as a flow Chart, this illustrates the hierarchy and one-to-many relationships. For example, one project can have many organizations, one organization can have many contacts and stations, and each station can have chemical, physical and biological results associated with it.



The identification of what data we are managing, how it is related to each other (primarily how results are related to meta-data and QA/QC data) and for what functions provides the basis for choosing tools (hardware, software and support decisions) designing tables and the fields that should be in those tables, queries or searches on the data for analyses, interpretation and reporting.

Identifying these relationships allows for effective data management design, building of the database system, identifying the most appropriate hardware and software, individual table structures, individual fields and their relationships, and finally the connecting process to move data from storage to retrieval for such functions as analyses, interpretation and reporting. Hopefully, it is clear why knowing what information our decision makers need, variables, data and results and meta-data, is important for effective database design. What information must I manage in addition to results, along with results, to produce a meaningful product or information for my decision makers and how will I do that?

How do I define data base relationships?

There is no one way to do this or right / wrong way. Provided below are some possible questions to considered.

A. From the list of all types of data you are generating in Part A of this Step, try and diagram logical relationships. One way is to start with each variable and work up the chain of possible necessary information. For each dissolved oxygen mg/l result, what other information do you need to make a decision? Do you need dissolved oxygen saturation? Do you need temperature (because dissolved oxygen concentration is a function of in stream temperature)? Do you need to know when it was collected, how, by whom? Do you need to know where and how much detail about where? Do you need to know the information about the collector and/or laboratory? Do you need to identify this result with a grant, funder or project? Thus, the check list might be per variable:

   - Variable and associated results (what)
   - When
   - Where
   - How
   - Who collected and analyzed
   - Data quality objectives, QA/QC results or summary
   - Why, monitoring objective or associated decision maker, administrative function id, grant, funder, project id?

B. If possible the next list to generate is the possible functions you need to perform for:

   - Entry and transfer (how get data into system from field data sheets, laboratory, etc.)
   - Storage
   - Retrieval (for other processes)
   - Analyses starting point (review, summary statistics, graphics, statistical analyses, modeling, etc.)
   - Interpretation, conclusions and recommendations starting point (benchmarks, criteria, processes for formulation, etc.)
   - Reporting starting point (tables, graphs, text, pictures, maps, etc.)
   - Evaluation (of database management system, monitoring objective answered, of monitoring design, assessment type goals met, outcome achieved, progress toward watershed vision)

   If you completed Phase 1 and 2, you have a first cut at this from identifying decision makers information needs. If that was not possible, you conducted research, asked experts and peers, employ information from other process and the like and made a decision on a starting point for these listed items.

C. From a relationship diagram of what generating and what functions will be needed, determine the tools and process necessary to design a data management system. Tools include hardware, software and data base support decisions. If you do not have the expertise, willingness or resource to design your database, this is the type of information someone else will need to complete the task for you.

D. Determine unique identification for items that apply to you, project, organization, individuals, sites and sampling event. Regardless of what tools you employ (hardware / software) this provides an opportunity to integrate data integrity and for database system evolution. Many relational database software can provide the simplest form of a unique identification per item by assigning the particular record the next available record number.

- **Project Id** (#, standardized name, code combination)
- **Organization Id** (#, standardize name or abbreviation, code combination)
- **Station or Site Id**

  <u>For example</u>, if you have 5 monitoring projects, each with 10 stations. One possible coding scheme might be identifying each project with A-E and each station 1-10, so B3 is station 3 from project B. The computer, however, if asked to sort all this data will place A10 before A2, because it considers each digit individually. You could remedy this by changing numbers to A01, A02, etc. as long as the database is small. Reach > 99 or Z projects and ?. There are thousands of methods, at a minimum have one and document it, you can evolve easier with some system versus no system.

  Numbering sites from down stream to upstream is common but might not be as flexible to add or subtract locations. Including miles from mouth or source is common, but decreases querying flexibility. The more you break you data into discrete units allows you to query it in the greatest possible detail.

- **Sample event or sample trip identifier**. A unique way to identify samples that were collected at that location and time. Examples range from the next available record number, to a number barcode to a code that does mean something such as a combination of station id + date + time of sample. This event identifier provides the ability to subset the data into smaller, simpler data sets or tables because you can later re-combine the data, in variety of ways, because each event has a unique identifier.

  <u>For example</u>, say I collected dissolved oxygen, bug sample and a pebble count at the same time. The dissolved oxygen data lives in its own table or spreadsheet. The bug data lives in its own table or spreadsheet and so does the pebble count data. But, they all have the same sample event identifier. Thus, when I go to search and build a report for example, I can call up that sample event identifier and retrieve all the data from multiple tables or spreadsheets.

At a minimum be able to list what you are generating. The next minimum is to identify the starting point for the functions you need system to perform on the data. Ask for help to define relationships if need too. It is okay to not know everything. It is okay to ask for help. It is okay to identify a degree of confidence around what you decide. If your decision maker has this all determined, the degree of confidence might be high. If your decision maker does not, your degree of confidence may not be as high. What is not okay is to not decide, not identify the components and relationships. Degrees of confidence get strengthened by individuals who are willing to risk trying new things with low confidence and through evaluation increase that confidence for the next effort. Remember, everything started from scratch at some point. The nature of this work is not black and white, it is trial and error – learn and try again.

Sketch out a database design as best you can, that includes every data/result and meta-data generated, the relationship to each other and the processes to move the data through the system to generate information. Even if you don't know the answers, leave a box as a place holder.

E. Tips

- ✓ Once you have chosen a software understand its requirements, such as naming fields (eight letter limit). Design each field as appropriately, proper name, proper width, format (character, numeric, date, logical, etc.), decimal, indexed, etc.
- ✓ Maintain field names and field types across tables
- ✓ Make field names as explicit has possible, for example "phosphorus" as a field name, is it total phosphorus, ortho phosphate, phosphate, units?
- ✓ If using a relational database, use information that is not actual data or meta-data to provide the relationship link, like a next generated number
- ✓ Standardize naming, spelling and abbreviation schemes for locations, samples, personnel, codes, units, etc. Document standardization.
- ✓ Détermine unique site identifier. Détermine unique sample event identifier.

Hardware

Again, no easy one size fits all, right or wrong answer in selecting hardware. Regardless of what hardware you have, you can assess it against what your hardware need is today and for tomorrow. You can incorporate working toward what you need if you can identify those needs today. In all likelihood, your hardware and software choices need to support organization functions as well as database management functions.

The task here then is to assess your current and future hardware needs to support your data management system, so that it will transform data points into information for the desired decision and decision maker. So, whether you are starting from scratch or dealing with what you have based on a completed database management needs assessment (Part B above and a database design). Identify the best hardware. Take your list of what generating, relationships and diagram to experts, peers, friends and others doing the same work to find out what they use or can recommend. System components might include:

- ♦ Computer Processor Unit (CPU) storage capacity (hard drive) and active memory capacity
- ♦ CPU additional disc capacity type (floppy, CD, readable, writable data, DVD readable, writable data, internal, external)
- ♦ Modem, external/internal
- ♦ Internet access

- Server access
- Monitor
- Accessories (keyboard, mouse, printer, scanner, speakers, surge protectors, chords, etc.)

Software

Again, no easy one size fits all, right or wrong answer in selecting software. Again, what should drive the decision is what needs and functions you have. Regardless of what software you have, you can assess it against what your software need today and for tomorrow. You can incorporate working toward what you need if you can identify those needs today. In all likelihood, your software choices need to support organization functions as well as database management functions.

Spreadsheet or Relational Database or both?

At some point in this process of implementing an monitoring and watershed assessment program, this question will arise, perhaps within weeks or years. Both spreadsheets and relational databases are valuable. Both have pro's and con's. If you have an understanding of your data management system needs, then you can make the best choice today and plan for the future. The primary difference between these two database managers is how they are structured to store, manipulate and retrieve the data and then how you interface with those functions.

Spreadsheets are structured around tables that you interact with directly. The data resembles a table you are used to seeing in reports and text. The data are organized in numbered rows and lettered columns. Where a row and column intersect is called a cell. Each cell has a unique address. For example, the cell address where column D and row 3 intersect is "D3." You arrange your data within these tables however you wish. You can sort, re-arrange, search, and perform calculations on the rows and columns of data or on selected cells.

EXAMPLE

WATERSH	RIVER_CD	RIVER	KIT_NUM	SCHOOL	STA_NUM	SAMPLE_NUM	STATION	DATE	TIME
CO	21662	Rifle Cr	220	Rifle MS	548	548.001	RMS	11/16/1995	1710
CO	21662	Rifle Cr	220	Rifle MS	548	548.002	RMS	11/30/1995	1600
CO	21662	Rifle Cr	220	Rifle MS	548	548.003	RMS	2/13/1996	1615
CO	21662	Rifle Cr	220	Rifle MS	548	548.004	RMS	4/8/1996	1630
CO	21662	Rifle Cr	220	Rifle MS	548	548.005	RMS	5/5/1996	1415
CO	21662	Rifle Cr	220	Rifle MS	548	548.006	RMS	5/13/1996	1600
CO	21662	Rifle Cr	220	Rifle MS	548	548.007	RMS	5/17/1996	1615

CO	21662	Rifle Cr	220	Rifle MS	548	548.008	RMS	5/20/1996	1600
CO	21662	Rifle Cr	220	Rifle MS	548	548.009	RMS	5/28/1996	1330

Spreadsheets easily perform calculations, statistics, and graphical analyses. They also allow you to see all your data arrayed in tables, which you manually construct. Many spreadsheets now offer filtering and querying capabilities similar to databases. A spreadsheet template can be used and the form automated to perform calculations, statistics or graphing for repetitive situations such as multiple sites monitored or multiple dates. Most current spreadsheet software has a workbook (or 3-D) format where you can copy the format of the first "worksheet" in a stack and use each successive worksheet for a different date, or site or year depending on the number of sites monitored and samples or measurements taken. Common spreadsheet programs in use include Excel (Microsoft), Lotus 123 (IBM) and Quattro Pro (Word Perfect).

In the analogy that our data points and results are a variety of nuts and bolts that need organizing in order to find timely and build something, what we need is a slick organizer that has 100 little drawers with labels. Those drawers and labels would be organized logically, by size, type across and down. For example across might be size variations (large to small) and down might be type (for wood, metal and plastic). If you still need to open 10 drawers per request, maybe further refinement is needed, size might be divided into length, width and thread. The more the organizer is organized for you to find a piece when asked, the more effectively you will provide the piece-or information to your data users.

Spreadsheets might be akin to the slick 100 drawer organizers in that they can provide a variety of mathematical and statistical manipulations, easy graphing, easy to create tables and reporting formats. Spreadsheets are user friendly and simple to use for some cumbersome data manipulations. You can also build in data integrity mechanisms and data query or search abilities to some degree. Most spreadsheets have graphing functions as well.

Spreadsheets can be cumbersome for very large data sets and some database functions and relative to relational database software. Relational databases are more robust in their ability to incorporate data integrity, design queries and build reporting formats. For example, if you have multiple databases users (for input and outputs) you might run into duplication issues. If someone enters field data and meta-data and someone else enters nutrient lab data while a third enters fecal data, how will they all enter the site number, field collectors name, etc.? Relational database can provide a design where meta-data is entered once and available to multiple users for their use, reducing the need for duplicate information and the possibility of creating duplicate entries, thus increasing data integrity.

Relational Databases are structured around tables that you can interact with directly and indirectly. You can build a table and deal directly with it as you would a spreadsheet. You also can build a table and use it and never see it, because you interact with it through developed entry or reporting screens that employ several tables at one time.

The tables are much like spreadsheets, instead of organizing the data in to rows and columns, the structure is organized into *records* (row equivalent) and *fields* (column equivalent). For example, for the data in a phone book, an individual listing would be a record, alphabetically listed. The columns of Last name, first name, address and phone number would be fields. If you enter and retrieve data directly from this table, it behaves similar to the basic entry and retrieval of a spreadsheet. If this is all you need to do, the spreadsheet is probably a more user friendly intuitive tool.

Relational databases are a step up from that slick 100 drawer organizer. We might equate this to what an auto parts store or library can do versus that 100 drawer organizer. You walk into an auto parts supply store and need a specific part for your car model, make and year. They have these great reference books that help them find the right part. All these parts have unique identifiers, part numbers that help manufacturers, delivery folks and sales folks track the parts. Reference books are organized by part type, part number, model type or year, or a number of different ways so that when you come in with a part number, they can find it. Whether you come in with a part number, part description, car-type, or other, they can find it. Just like a librarian or bookstore can look up books by title, by author, by ISBN number. In essence they have created all these "relational" databases, reference manuals, and tables that allow them to look up or query for what they want from a variety of starting points.

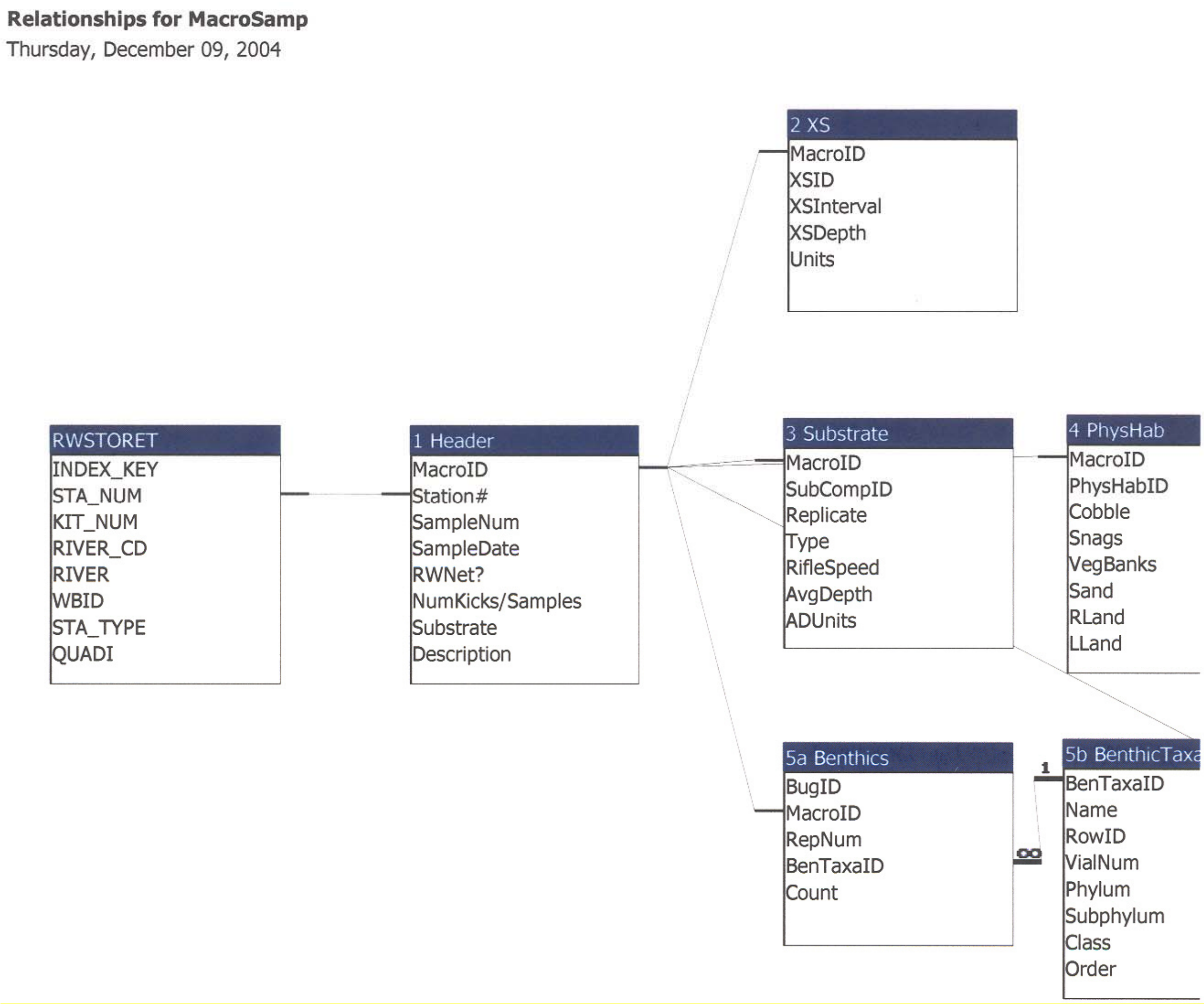
Imagine if you will, this type of information, all the information in those auto parts reference books were stored only in a spreadsheet format, where everything about gas cap # 456CAP-45968dts, size 3 was listed to the right of that part, as a spread sheet would do. It would be an inefficient and ineffective way to store the information for the manufacturer to store for the warehouse, the warehouse for the store, the store for its salesman and the salesman to retrieve for the customer.

The power of a relational database tool is that you can develop user specific screens for specific functions, including entry, validation, sub setting data, analyses and reporting. Relational databases can do this if you provide the relationships between all the data in the tables. Based upon these defined relationships, the screens you see employ many tables at one time. For example, I might the following multiple tables:

1. Project Table, each record or row is a project, and each column or field has information about that project like a unique identification number, name of project, start date, end date and a description.
2. Organization Table, each record or row is an organization, and each column or field has information about that organization, like unique identification number, name of organization, mailing address, phone, fax and websites.
3. Participant Table, each record or row is an organization, and each column or field has information about that organization, like unique identification number, name of organization, mailing address, phone, fax and websites.
4. Station Table
5. Sample Event Table
6. Chemical Results Table

For data entry I want to create a screen that for a specific project and organization, they can enter their chemical and biological data. I also want to create a report for this specific project and organization results. The screen a data entry user would see would employ all the tables I have listed above. The screen the report generator would see would employ all the tables I have listed above.

EXAMPLE



In this example RWSTORET is the station table, the fields are listed underneath, the next table underneath RWSTORET is 1 Header, it is meta-data about the macroinvertebrate sampling that will apply to all samples, below that are tables that hold results for 3 Substrate, 4 Physical Habitat, 5a Benthic sample meta-data, 5a taxonomic data. One station and sample meta-data can have many results for tables 3,4 5a-5b. The field names are listed below each table name. I could not enter a species in table 5b unless it is associated with a station in the RWSTORET table.

Thus relational databases allow you to store data into many, many logical tables or subsets of data, so that you can easily re-connect the tables for a variety of functions, such as entry, validation, searches, analyses and reporting. Each table has a “key” field that is unique and “connects” it to the table above it in the defined relationship hierarchy.

Spreadsheets do not have the ability to define relationships and thus for each table you need to "bring" along necessary meta-data for each function. For relational databases the focus is spent on defining relationships between the data tables and developing the function screens. The piece-mealing of data is indirect, behind the scenes. In spreadsheet databases, the focus is on making sure each table as all the information and it travels through all the functions, in a more direct piece-meal manner.

Relational databases allow for integration of more sophisticated data integrity mechanisms. For example, a data entry screen, will make sure that as you enter the data follow the database hierarchy of relationships defined. For example, if you stated that a dissolved oxygen concentration must have an identified sample event id, station id, organization id and project id, the data form will not allow you to enter a dissolved oxygen concentration without that information. In addition, data entry screens also can automatically check that the correct type (numerical versus text) or range of data (such as pH must be greater than 0 and less than 14) is entered.

A powerful tool that relational databases provide is the ability to search on specific criteria, sometimes called a query. You can design screens that will conduct a search or query, where the user is selecting the query criteria from a user friendly screen and the query is conducted behind the screen using multiple tables. This allows you to easily subset data to either analyze in the relational database or import to a spreadsheet for graphing, to make a table or analyses, to GIS for mapping or analyses, to a report to make a table, etc. For example a typical query might be "give me all the data for station X from 1994-1999". In a spreadsheet you could complete that query, but it would be by direct manipulation of searching, cutting and pasting most likely.

Relational databases allow for the creation of unique reports as well. Again this is because the software can re-combine the many tables behind the user friendly report screen, based upon the relationships you defined of the data.

There may be a special screen set up to enable you to select among a variety of search (sometimes called *query*) options. You can then set up report forms to organize the data you retrieve into a summary table. It requires substantial time to set up the database, design screens, and set up report formats. However, once this is done, it is very easy to enter, store, retrieve, and report the data.

Both spreadsheets and relational databases can conduct analyses. Relational databases can also turn the organization of row/column or record/field on its side and "normalize" the data. This normalize format is not user friendly at all in that the data is no longer in a logical table format, but turned on its side. Take the phone book example, un-normalized, row/column or record/field:

Identifier	Address	Phone
Smith, John	123 Blue Street	970/234-4567
Smith, Suzi	789 Fox Lane	456/968-5868

This same information normalized would look like:

This is not a user friendly format. However, it is electronically the most efficient way to store many small tables or subset of logical information, connected by identified relationships. Powerful and robust relational databases such as Oracle, is what EPA's STORET is designed and built in, precisely because it can store very large amounts of data efficiently for retrieval. Relational database software

"Off the shelf" include Access (Microsoft), Approach (Lotus), Filemaker (Claris), Paradox, Rbase and Dbase (not actively supported or available anymore).

A Relational Database Example

For example, let's say you have information on four station locations, who collected data and all the methods used. You record date, time, weather and comments for every event. And you collect and analyze for dissolved oxygen, temperature, 12 heavy metals, pH, and fecal coli form.

The data is generated in variety of forms. Station location information and sample/analyses methods are generated by program manager. Time, date, weather and comments are generated on paper by field sampler. Dissolved oxygen is generated by titration, recorded on hard datasheet. Temperature, measured by thermometer recorded on field data sheet. PH value is generated by a calibrated pH meter, calibration and pH values recorded on a field data sheet. Metal and fecal samples are collected, sent to a lab. Metals lab gives you an excel spreadsheet table of results that only have site location number and sample date. Fecal lab gives you a hard copy/report of the results.

You can visualize entering, cutting and pasting all the above generated data into a spread sheet. That might look like:

Location	date	time	who collected	PH method	pH value	etc.
Station 1	12/11/08					
Station 2	1/04/03					
…						

Or something equivalent that displays one station at time and all the associated results for that station on that date. Now imagine you have 10 years worth of data on these four stations, these variables only, except in year 7 you added nitrate to your list.

Now, data user 1 only wants meta data and fecal reported, monthly. Data user 3 wants meta data, methods, staff, station location and metals. Data user 4 wants everything but only for station 2, before 2003. Data user 5 wants something different. To produce all these "reports" would require a fair amount of double entry, cutting and pasting, simple linking between spreadsheet pages or something similar. It is not a very efficient way to store the data in order to retrieve variations on how it is laid out. It is very user friendly if I want to see information for each station on specific dates.

So, Spreadsheet …..or……Relational Database?

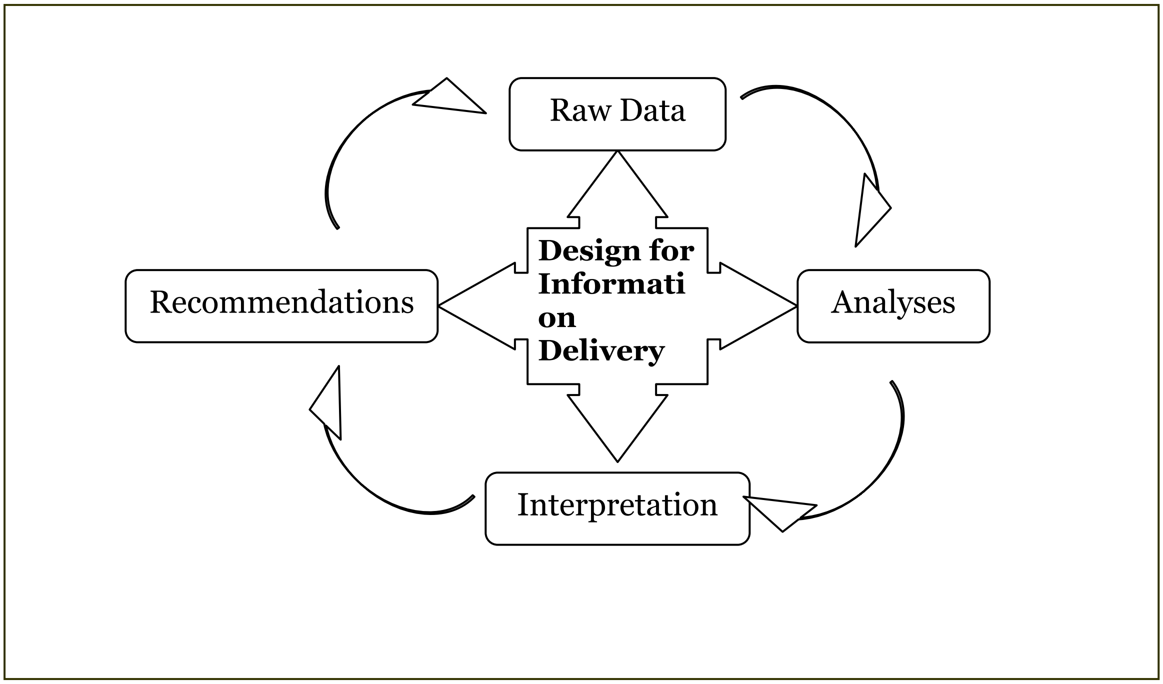
Both are valid tools. Tools, you may decide on one, not the other or both. We suggest you address your data management needs based on what data you are managing and what functions you need, and determine what serves those needs best you're your resources today and plan for tomorrow. There is no right or wrong answer, the following table summarizes the pro's and con's of each. This is followed by a check list of items you might weight in making your decision.

Table 1: Advantages and Disadvantages of Spreadsheets and Databases

Function	Relational Database	Spreadsheet
Volume of data	Better for storage of large, continuous, sets of data in long run	Better for storage small finite sets of data, deals well w/ imported subsets

		of data
Variety of data	Handles storing and combining wide variety of data	Stores wide variety, hard to combine dissimilar varieties efficiently
Combining meta-data with results, or different types of results	Easily once relationships and hierarchy is defined	Difficult with large volume, wide variety, can be cumbersome, do by hand
Entry	Can do directly to table or develop screen for multiple table entry, can integrate data integrity at entry point	Do directly to spreadsheet, minimal data integrity integration for entry
Validation/Data integrity/ formatting	Can develop automatic validation and integrity	Limited automatic validation and integrity, but some
Analyses - statistics	Can do, simple to complex, fewer analytical options, less intuitive and user friendly	Can do, simple to complex, wider array of analyses, more intuitive and user friendly
Analyses - graphing	Can't do	Most have a graphing component
Analyses – query or sorting, subsetting data	Easily once relationships and hierarchy is defined, across multiple tables, can do on fly or automate with screens, fairly intuitive once understand relationships	Limited within specific spreadsheets
Reporting	Easily once relationships and hierarchy is defined, across multiple tables, can do on fly or automate with screens, fairly intuitive once understand relationships, less intuitive to develop report forms	Can customize, easier and more user friendly to "make" pretty, more intuitive to develop reports
Templates and Screens to automatically construct entry, query, analyses and report forms/functions	Can do, less intuitive, more training/knowledge needed, powerful for using multiple tables, less intuitive, more training/knowledge needed	Easier, more intuitive, less training/knowledge, newer versions can set up like databases and use "workbooks" to link data in multiple sheets
Ability to define relationships within system	Yes, by design	No, by design
User friendly	Better than used to be, need more knowledge, intuition to figure out	Very, less knowledge and intuition to figure out
Integrity after entry	Built into relationship rules turn on	Not great, unless use pivot tables, then can help
Normalization	Can do with ease	Can do, much harder to do
Number of Users	Deals effectively with multiple users to ensure data integrity, reduces introduction of errors, duplication, etc.	More difficult to maintain integrity, error management and decrease duplicity with multiple users
Up front resources	More	Less
Resources to use	Less	More
Training and Knowledge to use, program an modify	More	Less
Street Cost	About same	About same

It is common among watershed monitoring and assessment database managers that have been around a while to use relational databases to store and retrieve the data for other functions such as analyses, interpretation and reporting. Thus, the relational database provides the data entry, data combining from multiple sources-as entry to the storage system, data validation and integrity, efficient storage, development of queries to subset the data and retrieval mechanisms. The query and retrieval mechanisms prepare the data to be transferred to spreadsheets for date-to-information functions (Phase 3) such as analyses, interpretation, reporting where you might need to make graphs, take data into spatial mapping software like Geographic Information Systems (GIS) for analyses and mapping, or to a statistical package or modeling software, for general retrieval on a webpage or for uploading to EPA's STORET. A decision maker might need any one of a data-to-information off ramp, see the next illustration.



It is possible to look at these tools at a local, regional an state scale and relate them to the available resources, level of knowledge and volume of data:

- At the local level: a citizen group might use Microsoft Excel and Access to input, store and conduct simple analyses, graphs and reports.
- At the state level: Each state health department has to use the EPA's STORET for data collected with EPA funds. STORET is how these agencies have to organize, enter, define relationships and store data for the EPA. They each employ software such as Microsoft Access, Excel and GIS for their analyses, interpretation, reporting and storage needs unrelated to EPA's requirements.
- At the regional level: water districts, watershed groups, educational institutions, regions within agencies may combine multiple smaller data sets for storage, analyses, interpretation, reporting and decision making across state boundaries.

Graphics

More than likely analyses of your monitoring data will require graphing of the data through space and time, in order to find outliers, observe possible trends or patterns and to help understand the story the data might be telling. Consider the complexity and level of these needs against available software options. Most spreadsheets provide the basic graphing needs. Many statistical software packages also have graphing capabilities associated with illustrating the statistics they provide. There is complex graphing software available.

In your inventory of what data you are generating, consider if you are generating any photos, illustrations, drawings, maps and the like. Often scanners come with the software needed to incorporate non electronic graphics. Of course digital cameras provide a new avenue as well.

Naming Conventions

It may not seem important or relevant when you first begin collecting data, but developing standardize naming conventions can be very helpful for data manipulations, management, analyses and reporting. This applies to monitoring plans that collect data from many sites, or few sites but many variables. The more consistent the reporting, recording and entry of information, the easier it is to use. Standardizing naming conventions affects field datasheets, database design and manipulation. Consider developing standardize conventions for the following items, the naming of:

- projects,
- organizations,
- stations,
- variables,
- units and
- assorted meta-data:

Review the list of data that your are generating and identify places that could use standardize naming conventions. Document those conventions in the *Data Management Plan, Part 1*.

EXAMPLE

Category	Item	Naming Convention
Organization Name	High School and Middle School	**HS and MS (no periods, case sensitive)**
	Academy	**Acad (no periods, case sensitive)**
	Institution	**Ins (no periods, case sensitive)**
Org Numbering	XXX	**1 to 3 digit unique number, such as 4, 34, or 114**
Station Name	Highway	**Hwy**
	Bridge	**Br**

Data thorns

Another data management decision to make that will support the movement of results through the system to information includes decisions about the miscellaneous thorns that come with the territory of managing this type of data. You may discover that, if you have multiple targeted decision makers, they might have conflicting information needs and thus present you with different data management needs in order to fulfill two different reporting needs. Miscellaneous thorns are those little details that often distinguish between whether a targeted decision maker will use you're your data or not.

For example data user 1 may need you to report zinc detection limits for values that were below detection limits and data user 2 might need you to report zero's for the same situation and data user 3 asks you report ½ the detection limit. So, if your zinc detection limit is 10:

- for data user 1 you would report "<10",
- for data user 2 report "0" and
- for data user 3 report "5"

How do you design your data management system to manage that? The most efficient way is knowing what they each need ahead of time and if they don' t know what they need, you make the best decision you can and document why you chose what you did.

We have identified some common miscellaneous thorns for you to consider:

- Handling of detection, reporting or practical quantization limits (discussed above), see ***Step 5 Resource Guide*** for definitions and differences. You need to determine what you are generating or receiving from others. Typical options include when a value is detected but not within a comfort level to report a result or value, what is reported is either a 0, or "< detection limit" say <10, or report ½ of detection limit, say 5 if detection limit was 10. Purpose for option 1, 2 or 3 usually has to do with data analyses and interpretation needs which we will address further in the planning process.
- Recording non values, you didn't collect pH today, do you leave it blank, use another non meaningful value like -9 or a zero
- Recording zeros, how will you separate measurements that result in a 0 value from other meaning of 0?
- Data ranges, values that are part of a rating from 1 to 5 for example
- Narrative results, such as "to few to count", riparian zones that are "un-impacted", "signs of erosion", "man-made" for example
- Significant digits, if your pH meter reads to the 100ths digit but it's not significant what will you record? If your titration apparatus reads in 10ths, 6.5 for example, and you get a reading like 7.54, how will you round it or record it consistently?
- Units, standardize units and/or conversions between Celsius and Fahrenheit, conductivity units, microgram versus milligram, etc.
- Impossible results, electronic databases help with this aspect in that you can design data entry to not allow for such numbers to be entered, for example pH values <0 or >14, dissolved oxygen values >18-20 mg/l.
- Rounding, errors introduced by software, manipulation or analyses is issue one, issue two is deciding how to consistently round if analyses produces results that are a finer resolution than significant digits. For example if analysis produces a result x.yzab and significant digits suggests you report only x.yy, how will you consistently round the "ab"?

User Considerations

Most likely the data management system and data will have multiple users over time and possible over space. Will there be multiple users or simultaneous multiple users? And of the multiple users should there be varying degrees of access? Do we need to distinguish between access to the data management system versus access to the data itself? Think about today and in the future about the users of this database management system. Who needs to access it for what purpose (operation and maintenance of the data system or just data use?), when do they need access, where and how will they get access to the data or system.

A tiered approach to access is helpful for planning both access to the data management system and to the actual data results. Reasons for having multiple tiers of access are usually associated with role/responsibility, level of knowledge/skill and data integrity or validation but can include considerations regarding sensitive data (data that might be used in legal proceedings or about endangered species for example). Your database design and chosen hardware/software can build in degrees of access and ability to change and edit and the ability to create read only type files. Determine what might be appropriate or valuable for your data management needs.

The issue of multiple users or simultaneous multiple users is most helpful to identify as a significant decision component of the final database design and selected hardware/software and system support decisions. Will you have multiple users or folks who need to be either:

1) Contribute information to the same larger database, at the same time or at different times, an example might be a field technician, lab technician and data manager all provide data to the same large database. If the timing is hierarchal, it travels from one to the next adding on, then that is one process to monitor. If access is needed at the same time or is not hierarchal but generated in a inconsistent timing, a different process needs to be developed and monitored.
2) Need the same information in their database as another data base has, and they are not linked. For example Lab 1, technician 2 and program manager 1 all need station location data and contact information in their respective tables. Would they each enter this information separately, duplicating the effort and introduce errors? If so you would need processes to monitor this to maintain data integrity. Or would create a central database, with a defined relationship, so that all can access that information in context with their work, but not need to enter it? There are technologies to handle this issue. You need to plan how to address it to minimize errors.

Process tools (forms, logbooks, etc.) that assure and control system

As you diagram how each data/result is generated, stored, retrieved for the various functions of validation, analyses and reporting, you will develop process and tools that move the data from one step to the next, from one place to the next. These tools and processes are part of the data management system support decisions you make in order to maintain data integrity, move the data through the system and evaluate the system at various points. These tools may be electronic or paper, they may be mini-processes that are document, but they exist informally and formally. We are suggesting you try and identify them and illustrate them in your overall data management system. Some examples might include:

- A data entry log sheet that tracks the electronic entry of hardcopy field data sheets
- A validation box on every field data sheet or as a field in the table that is marked or selected when the data is validated
- A form that documents for every batch of samples run through the XYZ machine, all laboratory blanks, duplicates and spikes were good, or if not what action was taken. These forms are placed in a notebook and reviewed a planned frequency
- A report from the macroinvertebrate laboratory listing the problems with the samples it received. This report is reviewed annually and changes to sample protocol, sample preservation or recording are made and documented. These reports on kept on file in XYZ building.

Safety Archiving, Backing up and Cross Training

This section is part of the system support decisions to make your each data point or result move through the data management system with integrity for reporting and delivery to targeted decision makers. Specifically, the decisions here relate to how you plan to protect your data from electronic failure or fire/theft, and how you might archive hard/electronic data for long term storage and institutional memory.

Safety. Safety of your data, hard or electronic happens through planning not accident. For hard data, field datasheets, maps, photos and the like, consider the value and need for protection from fire, theft and simple misplacement. We tend to operate in the now and not think much about 50 or 100 years from now. But, think long term, it is not unimaginable at all to believe that your photos, maps and data might be more valuable in the future than they are now. Maybe it is a picture you took that people use in 50 or 100 years to say, "look this is how the river looked 50 years ago, see how we have preserved it (hopefully) or see how we need to restore it"? So help the future help themselves.

Archive and Back up. For electronic data this means planning how and when you will back up what portions of your electronic database. Don't be the 3 in 4 folks who learn the hard way to back it up, and back it up twice. There are those that have lost their data and those that will, from lack of backing it up. It is not uncommon or considered excessive at all to have two back up copies of your data that are stored in differently locations and possibly have different "timed" back ups. You never know when you hard drive might go south, your computer stolen or a disc goes bad—you don't plan those events so you need to plan your back ups. It is also common to date your backups and know what changes might have occurred in between each back ups. You may need to stagger various components timing in order to '"recreate" an accurate lost version. Murphy's law says if you do it you won' t need it, but if you don't, you will—and won't have it.

Regarding your meta-data. You may need to decide how to handle names of staff or volunteers that have moved on, or stations that are no longer sampled, etc. You might even create a database of your staff and their level of training. You might change a method in the middle of a sample project. If the meta-data is valuable information in for the development of the story or data transforming into information, then keep it available.

Cross Training. More than likely more than one person is involved in managing your data. To the extent possible you want to design cross training into your organization, perhaps for more that just data management, but a least for data management. Your data is too valuable and cannot be regenerated in most cases, the date of collection is past. By having at least two people understand data management processes and systems, if something happens to one or the other you are not left in the lurch.

Elements of Your Data Management Plan, Part 1

Recap this step. You may not have needed to address all the items for which information is provided, that is up to you and your situation. We are suggesting at a minimum that you:

Part A - What managing how?

1) Have an inventory of what data/results and meta-data you are generating that needs managing, including the needs of your decision makers. This may or may not result in a minimum data elements list that you require or recommend that accompany this set all the way through data management to support the processes of analyses, interpretation, reporting and delivery of information to targeted decision makers.
2) Illustration of how data will flow through the major data management processes of entry, validation, storage, retrieval for analyses, interpretation, reporting and delivery. Where, what evaluation will occur and who is responsible. How will move data through the data management system,—more after Steps 13-16 in this Phase 3.

Part B - Data Management System Support Decisions:

3) Database Design and identified relationships
4) Hardware and software status and needs, including graphics, GIS and Web interface needs
5) Identified and documented naming and numbering conventions, miscellaneous thorns (detection limit, etc.), user considerations, process tools, safety measures, archive protocols, and training plan

Case Study 1:

Case Study 2:

References

See References Phase 1, Step 5 regarding data quality objectives for data management implications

See ***Step 5 Resource Guide*** for determining significant digits, rounding procedures and how to handle data management of detection limit, practical quantitative limit and reporting limit if you need to.

Guidance for the Data Quality Objectives Process EPA QA/G-4, USEPA, Office of Environmental Information, Washington, D.C. EPA/600/R-96/056, August 2000, www.epa.gov (on-line).

www.edwardtufte.com, author of several books on how to visually display complex information such as data base relationships, books and courses, *Visual Display of Quantitative Information, Envisioning Information and Visual Explanations.*

Resources

Contents in Phase 2, Step 11 Resource Guide:

1) National Water Quality Monitoring Council Minimum Data Requirement Template
2) Colorado Water Quality Monitoring Council Minimum Data Requirement Template
3) EPA's STORET Minimum Data Requirement, http://www.epa.gov/Storet

RESOURCE GUIDE

Step 11: Management of Raw Data (Data Management Plan Part 1.

Contents

1. National Water Quality Monitoring Council Minimum Data Requirement Template
2. Colorado Water Quality Monitoring Council Minimum Data Requirement Template
3. EPA's STORET Minimum Data Requirement

National Water Quality Monitoring Council Minimum Data Element Template

1.0 Contact	
1.1 Sources of Data (Alternate Names: Data Owner, Data Source, Sampling Entity, Laboratory Name and Address)	This element identifies the primary sources or providers of data to the system, whether within or outside the agency, including: name, address, telephone number including area code and e-mail address of the agency to direct questions about the sample analytical results.
1.1.1 Organization Formal Name	The legal, formal name of an organization that is the primary source of data.
1.1.2 Mailing Address	The exact address where a mail piece is intended to be delivered, including urban-style street address, rural route, and PO Box.
1.1.3 Mailing Address City Name	The name of the city, town, or village where the mail is delivered.
1.1.4 Mailing Address State Name	The name of the state where mail is delivered.
1.1.5 Mailing Address ZIP Code/ International Postal Code	The combination of the 5-digit Zone Improvement Plan (ZIP) code and the four-digit extension code (if available) that represents the geographic segment that is a subunit of the ZIP code, assigned by the U.S. Postal Service to a geographic location to facilitate mail delivery; or the postal zone specific to the country, other than the U.S., where the mail is delivered.
1.1.6 Telephone Number	The telephone number including area code of the person who is the point of contact for an establishment.
1.1.7 Electronic Mail Address Text	The text that describes an electronic mail address of a person located at an establishment.
1.2 Sampling Entity/Person	Name, address, telephone number including area code and e-mail address of the organization or person to direct questions about the sample collection.
1.2.1 Sampling Entity/Person Formal	The legal, formal name of an organization that is the

Name	sampling entity.
1.2.2 Mailing Address	The exact address where a mail piece is intended to be delivered, including urban-style street address, rural route, and PO Box.
1.2.3 Mailing Address City Name	The name of the city, town, or village where the mail is delivered.
1.2.4 Mailing Address State Name	The name of the state where mail is delivered.
1.2.5 Mailing Address ZIP Code/ International Postal Code	The combination of the 5-digit Zone Improvement Plan (ZIP) code and the four-digit extension code (if available) that represents the geographic segment that is a subunit of the ZIP code, assigned by the U.S. Postal Service to a geographic location to facilitate mail delivery; or the postal zone specific to the country, other than the U.S., where the mail is delivered.
1.2.6 Telephone Number	The telephone number including area code of the person who is the point of contact for an establishment.
1.2.7 Electronic Mail Address Text	The text that describes an electronic mail address of a person located at an establishment.
1.3 Laboratory/Field (Alternate Names: Laboratory Name and Address)	Name, address, telephone number including area code and e-mail address of the organization to direct questions about the laboratory analysis. Field denotes measurements conducted in the field.
1.3.1 Laboratory Formal Name	The formal title of the laboratory facility.
1.3.2 Mailing Address	The exact address where a mail piece is intended to be delivered, including urban-style street address, rural route, and PO Box.
1.3.3 Mailing Address City Name	The name of the city, town, or village where the mail is delivered.
1.3.4 Mailing Address State Name	The name of the state where mail is delivered.
1.3.5 Mailing	The combination of the 5-digit Zone Improvement Plan

Address ZIP Code/ International Postal Code	(ZIP) code and the four-digit extension code (if available) that represents the geographic segment that is a subunit of the ZIP code, assigned by the U.S. Postal Service to a geographic location to facilitate mail delivery; or the postal zone specific to the country, other than the U.S., where the mail is delivered.
1.3.6 Telephone Number	The telephone number including area code of the person who is the point of contact for an establishment.
1.3.7 Electronic Mail Address Text	The text that describes an electronic mail address of a person located at an establishment.

2.0 Results	
2.1 Result Value	Reportable numerical measure of the result for the chemical or microbiological analyte, or other characteristic, being analyzed.
2.1.1 Result Value Unit of Measure Name	The name of the determinate quantity for a standard of measurement used for measuring dimension, capacity, or amount of something (e.g., g/L, pCi/L, CFU/mL, etc.).
2.2 Analyte Name (Alternate Names: Analyte, Analyte Name, Constituent, Contaminant, Parameter, Chemical, Taxon, Metric, Index)	The name assigned to a substance or feature that describes it in terms of its molecular composition, taxonomic nomenclature or other characteristic. This field is optional if the analyte is adequately described in one of the following subelements.
2.2.1 Chemical Identifier/Number (Chemicals only) (Alternate Names: EPA Preferred Number, Constituent Identification Number; Contaminant; Chemical)	Chemical Identifier/Number is the unique number assigned to all chemical substances in the Chemical Abstract Service's (CAS) Registry or, in the EPA Chemical Registry System, to chemical groupings for which CAS Registry Numbers do not exist and cannot be assigned.

2.2.2 Biological Identification Number (Alternate Names: ITIS Taxonomic Serial Number, ICTVdB Taxon Identifier, EPA Biological Registry System Number)	The unique identification number assigned by either the Integrated Taxonomic Information System, (ITIS) the International Committee on Taxonomy of Viruses, or the EPA Biological Registry System .
2.2.2.1 Biological Systematic Context Name (Alternate Names: Biological Context Name, Biological Group Context Name)	The name of the classification system used to assign a systematic name to a biological entity.

3.0 Reason for Sampling	
3.1 Reason for Sample Collection See also 6.1 Sample Type	A text field to include such reasons as: (a) Reconnaissance/Occurrence Survey (b) Trend analysis (c) Permit Compliance (d) Pollution Event (e) Storm Event (f) Research (g) Regulatory benchmark (h) Bioaccumulation (i) Deposition (j) Other entries as applicable

4.0 Date/Time	
4.1 Sample Collection Start Date	The calendar date when collection of the analyte was started, reported as 4-digit year, 2-digit month,

(Alternate Names: Date; Sample Collection Date; Sampling Date; Year, Month and Day)	and 2-digit day in YYYYMMDD format.
4.2 Sample Collection Start Time Measure (Alternate Names: Time; Sample Collection Time; Collected; Collected End; Hour and Minute; Hour, Minute and Second)	The measure of clock time and time zone when collection of the analyte was begun, reported as a 24-hour day with 2-digit hour, 2-digit minute, and 2-digit second.
4.3 Sample Collection End Date (Alternate Names: Date; Sample Collection Date; Sampling Date; Year, Month and Day)	The calendar date when collection of the analyte was finished, reported as 4-digit year, 2-digit month, and 2-digit day in YYYYMMDD format.
4.4 Sample Collection End Time Measure (Alternate Names: Sample Collection Time; Collected; Collected End; Hour and Minute; Hour, Minute and Second)	The measure of clock time and time zone when collection of the analyte was finished, reported as a 24-hour day with 2-digit hour, 2-digit minute, and 2-digit second.

5.0 Location	
5.1 Water Body/Aquifer Name (Alternate Name: Receiving Water Name)	Name of the lake, stream, river, estuary, aquifer, reach name in the National Hydrography Dataset or other water feature related to the physical site.
5.2 Sample Station Identifier (Alternate Names: Sampling Station/Facility Identification	The name or number that uniquely identifies the sample station.

Number; Site Number, Well Identifier)	
5.3 Sampling Station Type Name (Alternate Names: Facility Type; Site Type)	The descriptive name for a type of sampling station. The valid sampling facility choices are: (a) Ambient (i) River/Stream (ii) Canal Drainage Irrigation Transport (iii) Lake (iv) Wetland Estuarine, emergent Estuarine, forested Estuarine, scrub-shrub Lacustrine, emergent Palustrine, emergent Palustrine, forested Palustrine, moss-lichen Palustrine, shrub-scrub Riverine, emergent Constructed (v) Reservoir (v) Riverine Impoundment (vi) Estuary (vii) Tidal Fresh (viii) Tidal Brackish

	(ix) Ocean (x) Great Lake (xi) Well (xii) Subsurface unsaturated/vadose zone (xiii) Spring (b) Water Supply/Source Influent (i) Raw/untreated water (drinking/com/ind) (ii) Finished/treated water for drinking (A) From treatment system (B) Entry Point to the distribution system after treatment (C) Within the distribution system (D) End of the distribution system with longest residence time (E) Point in distribution system with lowest disinfection residual (F) Household/drinking water tap (iii) Unknown (comment field) (c) Within treatment process (comment field) (d) Wastewater/Effluent (i) End of pipe (ii) Within mixing zone (iii) Downstream from mixing zone
5.3 Sampling Station Type Name (continued)	(h) Mine/Mine Drainage (i) Landfill

(Alternate Names: Facility Type; Site Type)	(j) Waste Pit (k) Other entries as applicable
5.4 Latitude Measure (Alternate Names: Latitude; Latitude of Sampling Station)	The measure of the angular distance on a meridian north or south of the equator in degrees, and decimal degrees.
5.5 Longitude Measure (Alternate Names: Longitude; Longitude of Sampling Station)	The measure of the angular distance on a meridian east or west of the prime meridian in degrees, and decimal degrees.
5.6 Latitude/Longitude Accuracy	
5.6.1 Horizontal Accuracy Measure	The measure of the accuracy (in meters) of the latitude and longitude coordinates.
5.6.2 Source Map Scale Number	The number that represents the proportional distance on the ground for one unit of measure on the map or photo.
5.6.3 Coordinate Data Source Name	The name of the party responsible for providing the latitude and longitude coordinates.
5.7 Latitude/Longitude Method	
5.7.1 Horizontal Collection Method	The method used to determine the latitude and longitude coordinates for a point on the earth.
5.7.2 Horizontal Reference Datum	The code that represents the reference datum used in determining latitude and longitude coordinates. Can include the NAD27 North American Datum of 1927, the NAD83 North American Datum of 1983, the World Geodetic System of 1984, or other entries as applicable
5.7.3 Reference Point (Alternate Names: Sample Point Identifier)	The place for which geographic coordinates were established. Entries may include: - Facility/Station Building Entrance or Street Address

	- Facility Center/Centroid - Boundary Point - Intake Point - Treatment/Storage Point - Release Point - Monitoring Point **- Other entries as applicable**
5.8 Altitude of the Sampling Station	
5.8.1 Vertical Measure (Alternate Name: Elevation, Altitude)	The measure of elevation above or the depth below a reference datum.
5.8.1.1 Vertical Collection Method	The method used to establish the elevation or depth of the sampling site
5.8.1.2 Vertical Reference Datum	The reference datum used to determine the vertical measure
5.8.1.3 Vertical Measure Unit of Measure	The unit for expressing the vertical measure
5.9 Altitude of Sampling Station Features	
5.9.1 Water Level (Alternate Names: Depth to Water)	(a) Surface Water: (i) Quantitative measurement of water level: The level of the water surface at the sampling point. (ii) Qualitative measurement of water level: (A) Tidal (1) High (2) Low (B) Stream Stage (1) Flood (over bank) (2) High (3) Medium

	(4) Low (b) Ground Water: The vertical distance from the land surface to the water surface level in a well
5.9.1.1 Water Level Unit of Measure	The unit for measuring the water level, where applicable.
5.9.2 Bottom Depth Measure (Surface Water)	The measure of the distance from the water surface to the channel or lake bottom.
5.9.3 Depth at Completion Measure (Ground Water)	The measure indicating the total depth of the well upon completion of construction.
5.9.3.1 Bottom Depth/Depth at Completion Unit of Measure	The unit for measuring the distance from the surface to the bottom..
5.9.4 Depth to Top of Well Open Interval (Alternate Name: Depth to Top)	The depth to the top of the open interval. Openings are permeable portions of the well casings or lining. Openings may be protected with screens, fractured rock, or other devices/materials.
5.9.4.1 Depth to Top of Well Open Interval Unit of Measure	The unit for measuring the distance down to the top of the open interval
5.10 Altitude of Sample (Alternate Names: Sample Collection Water Depth)	The numerical measure of the vertical location of sample collection.
5.10.1 Sample Depth/Altitude Units Text (Alternate Names: Sample Collection Water Depth Unit of Measure)	The text that describes the units for sample Depth/Altitude.
5.11 Water Discharge Rate Value (Alternate Names: Flow, yield)	The numerical value of the discharge rate of the water being sampled
5.11.1 Water Discharge Rate Unit of Measure	The text that describes the units for the discharge rate of the water being sampled

6.0 Sample Collection

6.1 Sample Type (Alternate Names: Quality Control Sample Type)	The type of sample being described. Permitted values include: (1) Field Measurement/Observation (a) Routine Measurement/ Observation (b) Replicate Measurement/Observation (2) Sample (a) Routine Sample (b) Field Blank (c) Field Replicate (d) Depletion Replicate (d) Integrated Time Series (d) Integrate Flow Proportioned (g) Integrate Horizontal Profile (h) Integrated Vertical Profile (i) Composite Without Parents (j) Positive Control (Microbio.) (k) Negative Control (Microbio.) (l) Other entries as applicable (3) Sample Created from Sample (No subtypes recommended) (4) Composite Sample with Parents (No subtypes recommended) (5) Quality Control Sample (a) Trip blank (b) Reagent Blank (c) Equipment Blank (d) Pre-preservative Blank (e) Post-preservative Blank (f) Field Spike (g) Field Blank (h) Reference Sample

	(i) Measurement Precision Sample (j) Other entries as applicable
6.2 Media Sampled (Alternate Names: Sample Medium Code, Water Source Type, Water Body Type)	The environmental media sampled at a site. The environmental material about which results are reported from either direct observation or collected samples. Includes water, sediment, precipitation and other entries as applicable.
6.3 Sample Temperature	Temperature of the sample when collected
6.3.1 Temperature Unit Measure	Fahrenheit, or Centigrade
6.4 Sample Identification (Alternate Names: Sample Number, Sample Identification Number)	The unique name, number, or code assigned to identify the sample.
6.5 Sample Collection Method	The method used to collect the sample: (a) Surface Water (i) Grab (ii) Pump (iii) Collection filter - positive charge (iv) Collection filter - negative charge (v) Insitu monitor (probe) (vi) Composite (A) Flow weighted (B) Proportional (C) Cross sectional (D) Integrated Depth (vii) Other entries as applicable (b) Ground Water

	(i) High flow submersible pump (specify water flow rate) (ii) Low flow submersible pump (specify water flow rate) (iii) Bladder pump (iv) Bailer (v) Other entries as applicable (c) Precipitation/Atmospheric (i) Grab (ii) Pump (iii) Collection filter - positive charge (iv) Collection filter - negative charge (v) Continuous (specify water flow rate) (vi) Other entries as applicable
6.6 Sample Preservation / Treatment	
6.6.1 Container Type	Free text: Sample container type
6.6.2 Container Color	Free text: Sample container color
6.6.3 Container size	The container size used in sample collection
6.6.3.1 Container size unit of measure	The unit of measures used in specifying the container size
6.6.4 Sample collection filtering (Alternate Name: Sample	Filtered, unfiltered, or the specific fraction

Fraction)	
6.6.5 Chemical preservation method	The method used to preserve the sample in the field by the sampling entity. This entry is intended to include preservation techniques that are NOT specified as part of the Analytical Method, element 7.1: (a) Chemical added (1) Acidification (2) Antioxidant (3) Mercuric oxide (4) Other (comment field) (b) None (c) Other entries as applicable
6.6.6 Temperature preservation method	The method used to preserve the sample in the field by the sampling entity. This entry is intended to include preservation techniques that are NOT specified as part of the Analytical Method, element 7.1: Temperature Preservation Method. Suggested entries include: (a) Wet Ice (4 deg C) (b) Dry Ice (-78.5 deg C) (c) Cold Packs (4 deg C) (d) Refrigerated (4 deg C) (e) Frozen (0 deg C) (f) Frozen (-20 deg C) (g) Frozen (-50 deg C) (h) Freeze Dried (i) None (j) Other entries as applicable
6.10 Sample volume	The numerical value of the volume of the sample
6.10.1 Sample volume unit of measure	The unit of measures used in specifying the sample volume

6.11 Sample weight	The numerical value of the sample weight
6.11.1 Sample weight unit of measure	The unit of measures used in specifying the sample weight

7.0 Sample Analysis	
7.1 Extraction/Processing Date	The calendar date when an extract for a sample analysis was taken for sample analysis, reported as 4-digit year, 2-digit month, and 2-digit day.
7.2 Extraction Process Time	The measure of clock time and time zone when the extraction of the sample was completed, reported as a 24-hour day with 2-digit hour, 2-digit minute, and 2-digit second.
7.3 Analysis Date **(Alternate Names: Date; Year, Month, and Day)**	The calendar date when analysis of the analyte was finished, reported as 4-digit year, 2-digit month, and 2-digit day in YYYYMMDD format.
7.4 Analysis Time	The measure of clock time and time zone when analysis of the analyte was completed, reported as a 24-hour day with 2-digit hour, 2-digit minute, and 2-digit second.
7.5 Analytical Method Number **(Alternate Names: Analytical Method, Method References)**	The method number of the analytical method used, represented as a reference number: (a) EPA (Specify number) (b) ASTM (Specify number) (c) SM (Specify number) (d) Other methods as applicable
7.6 Sample Size (Microbiologicals only)	The size of the sample used for analysis
7.6.1 Sample Size Unit of Measure	The unit of measure of the size of the sample, measured in Liters or milliliters.

(Microbiologicals only)	
7.7 Serial Dilution (Microbiologicals only)	The serial dilution is expressed as a numerical factor representing the number of equal volumes of dilute added to the sample and to be applied to the same units as the "Analytical Result Unit of Measure"
7.8 Composite Sample	Composite samples for microorganisms are: (a) Time (i) Flow weighted (ii) Proportional (iii) Cross sectional (iv) Integrated Depth (b) Flow (i) Flow weighted (ii) Proportional (iii) Cross sectional (iv) Integrated Depth (c) Spatial (i) Flow weighted (ii) Proportional (iii) Cross sectional (iv) Integrated Depth (d) Other entries as applicable
7.9 Run Batch (Alternate Names: Sample Batch Identification Number; Batch Number)	A lab-defined identifier for a batch of analyses done on one instrument that make up a sequence of analyses during which the instrument is continuously in control.
7.10 (Spiking) Amount or Dose Added	For Chemicals: The amount (weight or volume) or final concentration of an analyte that has been spiked into an aliquot at any time during the analysis process.

(Alternate Names: Spiking Concentration)	For Microorganisms: The dose of method organisms/cells added to a sample to be analyzed for calculating analytical precision and accuracy where the value reported use the same unit of measure reported for Analytical Results.
7.10.1 Spiking Amount or Dose Added Unit of Measure	The name of the determinate quantity for a standard of measurement used for measuring dimension, capacity, or amount of something (e.g., g/L, pCi/L, CFU/mL, etc.)
7.11 Analytical Precision (Alternate Names: Precision of Value)	A measure of the agreement among individual measurements of the same property in duplicate laboratory samples (duplicate laboratory spiked samples) under prescribed similar conditions to estimate variability in the measurement method or procedures. Precision is expressed as: (a) Standard Deviation (SD) SD= [{ (xi - avg x)2} / (n-1)] (b) % Relative Standard Deviation (RSD), % RSD = (SD / mean concentration) x 100 , or (c) Relative Percent Difference (RPD), RPD = [X1 - X2) / {(X1 + X2)/2}]x 100
7.12 Analytical Accuracy/Error (Alternate Names: Bias of Value; Analytical Accuracy Measure)	(a) Accuracy is a measure of confidence in a measurement and can be assessed by calculating: (i) % deviation % deviation = [(average x - true value) / true value] x 100; or (ii) % recovery (Rec) % Rec = [(amt. found in Spiked sample - amt. found in sample) / amt. in spiked sample] x 100 Accuracy describes how close a result is to the true value measured through the use of spikes, surrogates, standards, or performance evaluation samples. (b) Error (i) Type I error (False positive) - a numerical value indicating the magnitude of Type I error (ii) Type II error (False Negative) - a numerical value indicating the magnitude of Type II error
7.13 Controls	

7.13.1 Positive Control (Microbiologicals only)	Identification of organisms used for determining accuracy: Genus and species
7.13.2 Positive Control Result (Microbiologicals only)	The analytical result of measuring the positive control: Presence or Absence
7.13.3 Negative Control (Microbiologicals only)	Identification of organisms used for determining accuracy: Genus and species
7.13.4 Negative Control Result (Microbiologicals only)	The analytical result of measuring the negative control: Presence or absence
7.14 Detection / Quantitation Level Measure (Alternate Names: Detection Limit; Detection Level)	The measure that describes the quantity of analyte below which the sample analysis equipment will not detect the analyte accurately. If the lowest numerical value that a laboratory can report reliably for a test result based on the laboratory's experience with the method and equipment is different than the Detection Limit Measure and set by Statute or Regulation, then it should be reported as the Regulatory Reporting Level.
7.14.1 Detection / Quantitation Level Unit of Measure Name	The name of the determinate quantity for a standard of measurement used for measuring dimension, capacity, or amount of something (e.g., g/L, pCi/L, CFU/mL, etc.).
7.15 Detection / Quantitation Level Type (Alternate Names: Detection Limit Type)	The type of detection level used in the analysis of a chemical constituent: (a) Instrument detection level (b) Method detection level (c) Estimated detection level (d) Practical quantitation limit (e) Limit of detection

	(f) Long term method detection level (g) Regulatory reporting level . Drinking Water Maximum Contaminant Level . Water quality standard or criteria . Alternate concentration level (h) Other entries as applicable
7.16 QA/QC Exception Flags	Flags should allow for: Analyzed past holding time - Dual quantification difference> 40% RPD - Estimated value, quantification doesn't meet SOP criteria - Duplicate injection precision not met - Spike recovery outside of control limits - Spike out of calibration range
7.16.1 QA/QC Comment Field	Text noting other aspects of the quality assurance and control

Recommended CWQMC Shared Database Information

Database Management and Monitoring Coordination Committees

General comments.

The following list of recommended fields for any database that might be shared via a CWQMC website was assembled by the Database Management Committee and modified by the Monitoring Coordination Committee. This simplification of STORET and the NWQMC recommended fields is considered to be the MINIMUM amount of information to make the databases useable for comparisons among databases. These also improve the potential for addition to STORET. These fields focus on chemical data, and should be modified to accommodate biological data by the Aquatic Life Committee. This list does not specify the design of the database. **The Database Management Committee feels strongly about importance of proper design of a relational database to hold these data, and will provide a design upon request from the Council.**

Recommended fields.

Project agency name: unique name for each agency or group.
ProjectID: no duplicates allowed.
ProjectName: character field.
Project Description: memo-type field that can include however much information the user wishes to supply, for example, participating agencies, approach, dates, sampling techniques, findings, reports, web site, names of project personnel.
Project Purpose: character field with ,e.g. basic screening, regulatory compliance, site-specific trends (per upcoming decision tree from Monitoring Coordination Committee).
Project QA/QC: memo-type field with frequency of field duplicates, field blanks, analytical lab name, and corrective actions by lab/agency for problems—e.g. bad blanks.
ProjectContact: Name, address, telephone, email. Person who supplied data. (These may differ.)
Station ID: character field, no duplicates allowed.
StationName: character field. If no name exists, can just repeat the stationID.
StationType: stream, well, lake, canal, etc.
StationLatitude: standardize this as Degree-Minute-Second or decimal degree.
StationLongitude: standardize this as Degree-Minute-Second or decimal degree.
LocationDatum: NAD27 or NAD83. Define which datum was used for lat./long. (e.g. pre-1983 USGS maps would be NAD27; GPS systems should tell users which datum was used.)
Location Description: memo-type field with local permanent landmarks or other descriptive comments—e.g. sample in the thalweg, upstream of bridge.
Sample ID: character field, must be a unique identifier.
SampleDate: representative date or date that sample collection was started.
Sample Time: representative time or time that sample collection was started (military time).
Sample Type: grab, composite; if composite, code for duration of composite (hours, days, etc).
SampleMedium: water, sediment, fish tissue, etc.
SampleDepth: character field that contains depth, or range in depth.
SampleDepth Units: meters, feet, etc.
Result Name: e.g. pH, Temp., Calcium, Nitrate, etc.
Result Value: measured characteristic. Prefer numeric field, but could be character field.
Result Units: degrees, mg/l, ppm, ppb, ug/l, etc.
Result Fraction: total, total recoverable, dissolved (filter size?), etc.
Result Detection Limit:
Result Detection Limit Units: mg/l, ppb, etc.
Result Comments: memo-type field that can include user-defined information, e.g. whether the result is an estimate, average, less than (for below detection limit), how user made an average, sample preparation, analytical method, etc.

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STORET Database Description

Data in STORET is organized into five main information categories:

Organizations
The group or entity responsible for the data set, either for collecting and otherwise generating the data, or sponsoring the activity for which the data set was created;

Projects and Surveys
The activity during and for which the data set was created;

Sites
Also referred to as stations, carry the identification and description of the physical location at which monitoring occurs;

Samples
Water quality sampling, observation, and measurement activities that occur at these sites; comprehensive descriptors of the event during which samples were collected or the measurements performed;

Results
The findings of the sampling events, measurements, and field activities.

Organization

In STORET organizations are the primary owners of data and control access to it. Organizations own metadata (descriptions of their data). Organizations own project descriptions, and lists of organizations and people with whom they work. Organizations control a broad set of lists of their preferences or usual practices for monitoring activities. These lists may include aids to data entry (e.g. substances tracked by monitoring activities, habitat evaluation criteria, and so forth), equipment used in the field, methods used in their labs, bibliographic references, and many others. In STORET, organizations control their own data through the use of an organization-specific identification code provided by EPA, and passwords controlled locally. The identification code ties together an organization's projects, stations, and sampling data. To enter or modify an organization's data, a user must supply the proper password. Without a proper password, STORET restricts a user's access to "browse-only."

Projects and Surveys

STORET allows an organization to maintain descriptions, in summary form, of the projects and surveys it conducts. The descriptions contain essential information concerning purpose, procedures, standards and methods, and quality goals. The descriptions also include information on individuals who manage and participate in the projects. Project descriptions permit linking data quality objectives and other quality control plan items to a broad spectrum of data. In this way, the needs of users for data quality descriptors can be met with a minimum of data entry effort.

Each project in STORET can involve one or more sampling stations ("sites"), and a sampling station can participate in multiple projects. Field activities and their analytical results are linked directly to all the projects they support. Projects may in turn be linked to programs, and because programs may be defined broadly to include the projects of several organizations, data from any field activity may be easily shared among both organizations and projects.

Sampling Stations (Sites)

All data concerning field work is keyed to the specific location at which the field work is conducted, linking water quality measurements to the place they represent. Each STORET site has a point of reference, whose latitude and longitude are fully defined. In addition, each site may include an area boundary, a field of actual monitoring locations, and the descriptions of any permanent sampling grid or transect found there. For facilities, additional data may be entered for the individual end-of-pipe locations; for wells, a field of individual wells may be described.

Precise location definition is very important to environmental analysis, and EPA data standards for locational data are strictly followed in STORET. All applicable federal standards (FIPS, NIST, and others) are adhered to wherever possible as well.

Sites may be part of external reference schemes, and may carry a multitude of identifiers from each of these schemes. For example, a site in STORET might have an NPDES number and a state regulatory program code. Any site which contributes data to a project may be assigned a project-specific identifier.

STORET gives organizations several options for identifying their stations. Each station has a unique identifier, assigned at the discretion of the organization that "owns" the data. An organization can also assign multiple alias names to its stations. In addition, project managers can assign a unique name to each participating station that is meaningful within the context of their project. This allows a station to carry a different name in each project in which it participates. A site must first have its reference point defined before it may be assigned to one or more projects and sample collection may begin. This assures that all results are place-based. Organizations can maintain information on different types of sampling stations (e.g., well, spring, stream, ocean). The system provides a common set of geographic and descriptive information for all stations as well as information specific to the individual type of sampling station.

To assign a station to a project (i.e., to collect samples) requires a latitude/longitude coordinate [set] to be entered. STORET then takes this information -- known as the station's point of record -- and presents the user with candidate selections for the Federal Information Processing Standard (FIPS) State, County, and Hydrologic Unit Codes (HUC). STORET also allows an organization to add the latitude/longitude coordinates of a series of points to a station description, transforming the station from a single point to an area or polygon.

An organization can view and copy station descriptions belonging to another organization. Copying a station description allows an organization to include that station in its catalog of stations and makes the station available for assignment to the organization's projects.

Samples (and Station Visits)

Samples are described according to their medium and the intent for which they were collected. STORET accepts descriptions of the sample collection process which address the complete spectrum of water monitoring and sampling of the biological community. How a sample is collected is documented in STORET by links between a sample and lists of methods and equipment. Lists are available as part of the system, or client organizations may supply their own lists.

For large area samples, such as trawls, details such as the lat/long of its end points, gear deployment depth, and bottom conditions under the trawl can all be captured.

Samples can be created from other samples, by compositing, splitting, or subsampling. Each new sample is linked to its "parents" and can be traced back to all the events which might influence its results. A sample which is generated by a trawl (a "catch") might be the parent of a sample which is an individual fish. The fish in turn might be the parent of a sample which is a specimen of liver tissue, and chemical results for this liver specimen can thus be traced back to the spatial coordinates of the original trawl.

Field monitoring activities may be water, air, or sediment sample collection, biological specimen catch/trap events, or any measurements or observations obtained at the site. Each field activity is linked to those analytical results it generates (see results below).

Information gathered in the field through the process of measuring or observing the environment during the site visit is recorded in STORET as part of the site visit description. These data may include physical conditions of the site itself, status of any equipment permanently located at the site, biological habitat assessments, weather observations, and simple field-determined physical or chemical data. STORET can be used to document the frequency with which visits to sampling stations are to be conducted and to capture the results of a visit (samples collected, field measurements, and qualitative observations of conditions). Information about the sampling process, including standard procedures and methods, deviations from these methods, and sample management, may also be stored.

Station visit and sample information can be associated with a single station within a particular project.

Results

With STORET, results obtained through analysis of samples and "in situ" measurements can be recorded and attached to the visit/sample to which they relate. The system also stores metadata concerning the quality of results related directly to the results.

Each result is linked to a field monitoring activity. If the activity was the collection of a water sample, the results are qualified by all the methods used to collect, handle, store, and process that sample. The results may be further qualified by the identity of the lab performing the analytical work, and equipment and methods used in this process. STORET captures information about the participating laboratories and their qualifications. It also captures identifying information for the substances or properties being measured with qualifiers that enable valid data comparisons to be made. Statistical information concerning confidence intervals may be supplied, and for results which are not quantified, detection status and quantitation status may be stored. Results which are counts or percentages may be qualified by the range of some size or weight variable which they represent.

Biological results are handled in different ways. For a "catch", biota may be grouped and regrouped repeatedly for counting, weighing, or measuring. For example, one grouping might be by taxon, and the counts recorded for purposes of computing taxonomic diversity and richness, while another grouping might be a user-defined histogram or class frequency table of fish lengths within a species, and yet another might be to record counts and weights of only adults, or only gravid females, or any other category the analyst might request. A catch might be divided so that a group contains only 1 individual, and a detailed description of it recorded.